A Guide to Airborne Weapons

David F. Crosby

This informative guide provides clear and succinct descriptions of air weapons employed by the U.S. Armed Forces.

It includes a short description of each weapon, considerations for their special employment, characteristics, and their delivery aircraft.

The author identifies the primary manufacturer of each weapon and provides photographs or line drawings of them. Readers can use this book to bring themselves up-to-date on a rapidly evolving technology that is often in the news about the War on Terror.

Jacket Design by Teddy H Pound
Photos courtesy of the *US Navy* and *US Department of Defense*

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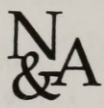

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PREFACE

A Guide to Airborne Weapons serves as a quick reference and helps to familiarize readers interested in the aerial-delivered munitions, tactical missiles, torpedoes, and gun systems currently used in combat by U.S. armed forces.

With this book, the reader can obtain a short description of the weapon, learn about any special considerations for employment, the weapon's characteristics, aircraft that can carry the weapon, the prime contractor that makes the weapon, and a photograph or line drawing of the weapon. The reader may notice identical wording being used to describe more than one type of weapon. This is intentional, as many systems share a majority of characteristics, and most people using the guide will be looking up an item rather than reading it from beginning to end.

The cost of weapons vary every fiscal year based on the number of weapons purchased and other factors (a missile may have models that used different seeker heads and other modular components that cause a variance in price as well). For this reason, the cost of a weapon is presented as an average or within a range.

A radical change has occurred in aerial warfare since the end of the Persian Gulf War. Gravity bombs accounted for 90 percent of the munitions dropped in that conflict. Precision weapons now account for about 68 percent of the munitions dropped in the War on Terror. In short, a bomb is no longer just a bomb. It may use a laser beam or the Global Positioning System (GPS) to locate its target. It may carry cluster munitions to kill troops in the open or a hardened warhead designed to burrow into concrete and destroy underground bunkers. With the proliferation of guided and special-purpose munitions, readers have need of a quick guide to help them understand news reports and current events. *A Guide to Airborne Weapons is that guide.*

While this book represents the most current and correct information available at the time of publication, combat is the mother of weapon innovation and improvements to old weapons and the birth of new weapons occur rapidly. Some of the latest weapons may not appear for that reason.

CHAPTER 1: Air Intercept Missiles (AIM)

Military Nomenclature: AIM-7PM/P

Name: SPARROW

Description: A medium-range, air-to-air missile (a missile designed to shoot down other aircraft) used by Air Force F-15 Eagle and F-16 Fighting Falcon and Navy F-14 Tomcat and Navy and Marine Corps F/A-18 Hornet fighters. The missile uses radar to acquire and track its target. The Sparrow can operate in all weather conditions and at all altitudes and can engage aircraft and missiles approaching from any direction. The Sparrow can operate in jamming environments and the H-Build variant can home on the jamming aircraft.

Employment Considerations: The Sparrow guides on radio frequency (RF) signals received from the aircraft that launched the missile and from RF energy reflected back from the target and received and processed by the missile's internal radar receiver. This method of engagement requires that the launch aircraft paint (lock on) the target with its radar and continue to paint the target until the missile strikes home. The need to paint the target limits the pilot to straight and level flight during engagement.

General Characteristics:
Speed: More than 2,660 mph (more than Mach 2)
Range: More than 25 miles
Length: 12 feet
Diameter: 8 inches
Weight: 510 pounds
Wingspan: 3 feet 4 inches
Warhead: The Sparrow uses two types of warheads-the WAU-10, which employs a continuous expanding rod with a 27-foot kill radius, and the WAU-17, which uses 36 pounds of PBXN-3 explosive to bring down the target with

traditional blast and fragmentation. Both warheads utilize proximity fuzes (a fuze that detonates the warhead when the missile enters within lethal range of the target) and weigh approximately 90 pounds.

Guidance System: Raytheon semi-active radar on continuous wave or pulsed Doppler radar energy.

Control: Four wings and four fins operated by hydraulic power give the missile flight control. An accumulator provides the hydraulic power in response to commands from the autopilot.

Propulsion: A Hercules MK-58 solid-propellant rocket motor powers the missile. The thrust generated by the MK-58 is still classified.

Cost: About $125,000

Date Deployed: 1982

Launch Aircraft: F-14, F-15, F-16, and F/A-18 fighters.

Contractor: Raytheon Co.

Ordnancemen load an AIM-7M Sparrow missile onto a F/A-18 Hornet. *Photo courtesy of the Department of Defense.*

Military Nomenclature: AIM-9M

Name: Sidewinder

Description: A short-range, heat-seeking, air-to-air missile that destroys it

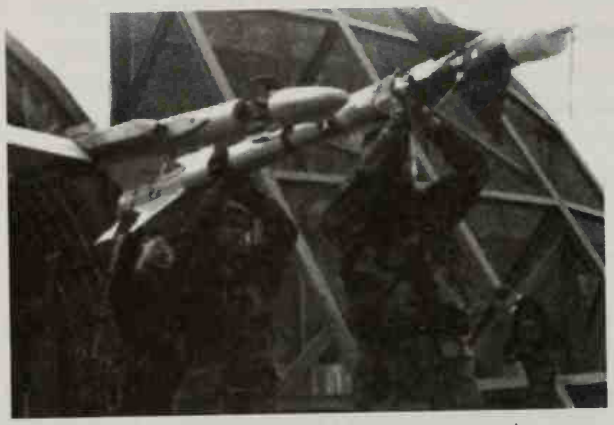
target with a high-explosive warhead. The Sidewinder can operate in all weather conditions and at all altitudes and can engage aircraft and missiles approaching from any direction. A heat-seeking guidance system allows the pilot to launch and leave the missile.

Employment Considerations: Infrared countermeasures such as targeted aircraft emitting flares can defeat heat-seeking missiles. While the AIM-9M can acquire a target approaching from any angle, it still works best when fired behind the intended target.

General Characteristics:

Speed: 1,875 mph (more than Mach 2)
Range: More than 10 miles
Length: 9 feet 6 inches
Diameter: 5 inches
Weight: 190 pounds
Fin Span: 2 feet 1 inch
Warhead: The Sidewinder destroys its target with a 20.8 pound annular blast fragmentation warhead that contains 7.9 pounds of PBXN-3 explosive. Because electronic countermeasures work against proximity fuzes that use RF energy to determine when to explode, the AIM-9M uses an optical fuze that explodes the warhead when infrared radiation (IR) energy it emits reflects back. The reflected IR energy tells the fuze it has closed within lethal range of the target.
Guidance System: The AIM-9M has an infrared radiation (IR) guidance system that can lock on heat generated by aircraft surfaces such as wing edges heated by air friction. Early models of the Sidewinder could lock only on engine exhaust and needed the launch aircraft behind the targeted aircraft before engagement.
Control: Four stabilizing wing and roller-on assemblies and four movable canards (small wings) operated by a servo assembly give the missile flight control.
Propulsion: A Thiokol Hercules and Bermite MK36 (Mod. 11) single-stage, solid-propellant, reduced-smoke rocket motor powers the missile.

Unit Cost: $41,300
Date Deployed: 1956
Launch Aircraft: A-10, AV-8B, F-14, F-15, F-16, and F/A-18 aircraft. The Marine Corps AH-1W attack helicopter also uses the Sidewinder to engage aerial targets.
Contractor: Lockheed Martin and the Raytheon



US Marines load an AIM-9M Sidewinder missile onto the wing of a F/A-18 Hornet.
Photo courtesy of the Department of Defense.

Military Nomenclature: AIM-9X

Name: Sidewinder

Description: The next generation Sidewinder designed to replace the AIM-9M. A short range, air-to-air missile with a state-of-art infrared (IR) guidance system, the AIM-9X has thrust-vectoring vanes that give the missile extreme agility during flight. Because the missile homes on a heat source using its internal IR guidance system, the pilot can launch and leave the missile. This feature allows the pilot to take evasive maneuvers during the aerial engagement. The AIM-9X's advanced seeker used in conjunction with a helmet-mounted sighting system offers a wide range of attack angles. The missile can acquire a target 90 degrees off its boresight (the direction of the nose of the missile).

Currently in low-rate initial production, the Air Force and Navy plan to buy more than 10,000 AIM-9X Sidewinders over the next two decades.

Employment Considerations: The ability to acquire a target at high angles and fly extreme maneuvers allows the missile to defeat a pilot flying a circular maneuver relative to the attacking aircraft—a tactic known as a Lufbery engagement. The AIM-9X can also engage an aircraft using the last-ditch evasive tactic of closing head-on at high speed.

General Characteristics:

Speed: More than 1,875 mph (more than Mach 2)
Range: More than 10 miles
Length: 9 feet 6 inches
Diameter: 5 inches
Weight: 188 pounds
Fin Span: 17.5 inches
Warhead: The AIM-9X uses the same warhead as the AIM-9M but with a new Electronic Safe-Arm Device (EASD). The EASD operates as both the safety and firing device for the warhead. It will arm only after it senses acceleration and achieves a safe separation distance from the launch aircraft. Because the AIM-9X executes radical maneuvers, the missile needed an EASD designed to survive extreme flight conditions. A proximity fuze instructs the EASD when to detonate the warhead. The proximity fuze uses an Active Optical Target Detector (AOTD) to determine when the missile has closed within lethal range of the target. To judge this distance, the AOTD emits pulsed IR energy. When the IR detector senses the IR energy reflecting back from the target, it sends an electrical firing signal to the EASD.
Control: The AIM-9X uses four forward-mounted wings made of titanium to provide aerodynamic lift and stability during flight.
Guidance System: A mid-wave IR Focal Plane Array seeker detects the target and an electronics unit converts the detected target information into tracking and guidance command signals. When an aircraft emitting IR (heat) enters the seeker's field of view, the electronics unit generates an audio signal. The pilot hears a signal through the headset, indicating the AIM-9X has located a potential target. The user of an AIM-9X has three methods of acquiring a tar-

get. The first method requires the pilot to physically point the nose of the missile (known as the boresight) at the potential target by maneuvering his aircraft. The second method involves the aircraft's radar. The Sidewinder Expanded Acquisition Mode (SEAM) slaves the AIM-9X seeker to the aircraft's radar. The radar turns the seeker of the Sidewinder toward the enemy aircraft until it acquires the target. The Sidewinder's seeker will then continue to track the target on its own. The pilot can also use the Joint Helmet Mounted Cueing System (JHMCS) to locate the target. The missile seeker will look where helmet movement indicates it should scan for targets. The seeker emits an audible signal when it has locked on a target. The pilot can launch the missile anytime after hearing the acquisition signal.

Control: The AIM-9X uses four forward-mounted wings made of titanium to provide aerodynamic lift and stability during flight. To maneuver the missile, the AIM-9X uses four servo-controlled, rear-mounted titanium wings mounted in line with the forward-mounted wings. To provide extreme maneuvering, the Control Actuation Section (CAS) uses a thrust vector control system which incorporates four jet vanes to redirect the rocket motor exhaust.

Propulsion: A MK36 single-thrust, reduced smoke, rocket motor with a thrust-control package that increases missile maneuverability.

Unit Cost: $200,000 to $350,000

Deployed Date: 2002

Launch Aircraft: F-14, F-15, F-16, F/A-18, and F/A-22 aircraft.

Contractor: Raytheon

An F-15 fires an AIM-9X. *Photograph courtesy of Raytheon.*

Military Nomenclature: AIM-54

Name: Phoenix

Description: A radar-guided, long-range, air-to-air missile that can operate in all weather conditions and in heavy jamming environments. Designed for use with the Navy's F-14 fighter, the Phoenix allows F-14 pilots to simultaneously engage as many as six targets at long range. Three models of the Phoenix remain in the US inventory – the AIM-54A (the first generation Phoenix), the AIM-54C, with improved features to counter threats from tactical aircraft and cruise missiles, and the AIM-54C ECCM/Sealed, which offers improved electronic counter-counter measures.

Employment Considerations: The long range of the Phoenix and the ability of the F-14's AN/AWG-9 weapon control system to handle multiple engagements allow the F-14 to engage and defeat aircraft before they can get close enough to the fleet to launch anti-ship missiles.

While the F-14 can upload a cluster of six Phoenix missiles, the heavy weight of the missiles (more than 6,000 pounds) increases wear and tear on the aircraft with each carrier landing. In reality, an F-14 rarely carries a full complement of Phoenix missiles. Most F-14 combat loads include lightweight and less expensive Sidewinder and Sparrow missiles and a few long-range and expensive Phoenix missiles because few suitable targets exist for the Phoenix missile (high-flying aircraft armed with anti-ship missiles).

General Characteristics:

Speed: More than 3,000 mph (Mach 4)
Range: More than 115 miles
Length: 13 feet
Diameter: 15 inches
Weight: 1,000 pounds (AIM-54A)
1,040 pounds (AIM-54C)
1,023 pounds (AIM-54C ECCM/Sealed)
Wingspan: 3 feet
Warhead: The Phoenix missile destroys its target using a 135-pound, high-

explosive warhead detonated by a proximity fuze.

Guidance System: The AIM-54 can use three different types of guidance – autopilot, semi-active radar, and active radar. After a long-range shot, an autopilot takes control of the missile and flies a pre-programmed route. When the missile enters midcourse, the nose-mounted radar seeker homes in on radar waves reflecting off the target from the F-14's radar. At 14 miles from the target, the Phoenix's own radar goes active and guides the missile to impact with the enemy aircraft.

Control: Four fixed delta-shaped wings and moveable tail-mounted control surfaces give the missile aerodynamic flight.

Propulsion: All three models of the AIM-54 missile use the Hercules MK 47 solid-propellant rocket motor.

Unit Cost: $477,131

Date Deployed: 1974

Launch Aircraft: F-14

Contractor: Raytheon

Ordnancemen prepare to load an AIM-54 Phoenix missile onto the wing of an F-14. *Photo courtesy of the Department of Defense.*

Military Nomenclature: AIM-120

Name: Advanced Medium-Range Air-to-Air Missile (AMRAAM)

Description: A medium-range, all-weather air-to-air missile with beyond visual-range capability designed as a follow-on to the AIM-7 Sparrow. Faster, smaller, and lighter than the AIM-7, the AIM-120 uses active radar making it less dependent on the launch aircraft's fire control system. As the missile nears the target, its radar goes active and it guides itself to the target. This capability allows the pilot to launch missiles against multiple targets and then "forget them" as he performs evasive maneuvers during the aerial battle. Should the target aircraft attempt to jam the AIM-120's radar, the missile will home on the source of the jam. The AMRAAM also offers improved capabilities against low-altitude targets. Three models of the AIM-120 exist in the inventory. The first production AIM-120A remains in the inventory, but Hughes no longer produces this model. The AIM-120A requires a hardware change to upgrade the missile software. The AIM-120B and AIM-120C remain in production and accept upgrades to the missile software through an umbilical. The AIM-120C has shortened control surfaces, which allow it to fit inside the internal weapons bay of the F/A-22.

Employment Considerations: The AIM-120's use of active radar and its capability to home on an aircraft jamming that radar allows the pilot to fire and forget the AIM-120 and take evasive maneuvers during aerial combat. The usefulness of the AIM-120 rapidly diminishes at ranges less than three miles.

General Characteristics:

Speed: More than 3,000 mph (Mach 4)
Range: More than 20 miles
Length: 12 feet
Diameter: 7 inches
Weight: 335 pounds
Wingspan: 20.7 inches (The AIM-120C uses shorter control surfaces to fit inside the internal weapons bay of the F/A-22.)
Warhead: The AIM-120 destroys its target with a 45-pound blast and

fragmentation warhead denoted by active radar when it is within lethal range of the target.

Guidance System: After a long-range launch, the AIM-120 uses its inertial guidance to head towards the target while receiving updated target information through a data link with the launch aircraft. As the missile nears the target, its own radar unit guides the missile towards the enemy aircraft. The missile's supersonic speed rapidly puts the AIM-120 in active radar range of the target. At closer ranges, the AIM-120 immediately activates its radar and needs no further guidance from the launch aircraft.

Control: Four stationary wings and four moveable control fins provide missile flight control. Ball fasteners allow for quick installation and removal of the wings and fins. The AIM-120C's shortened wings and fins (which allow it to fit inside the internal weapons bay of the F/A-22) are not interchangeable with the AIM-120A and AIM-120B missiles.

Propulsion: The AIM-120 uses a high-performance, solid-propellant, reduced-smoke rocket motor to boost and sustain the missile to supersonic speed.

Unit Cost: $386,000

Date Deployed: 1991

Launch Aircraft: F-14, F-15, F-16, F/A-18, and the F/A-22.

Contractor: Raytheon

An armament technician checks on AIM-120 mounted on a F-16CJ Fighting Falcon. *Photo courtesy of the Department of Defense.*

Chapter 2: Air-to-Ground Missiles (AGM)

MILITARY NOMENCLATURE: AGM-65

NAME: MAVERICK

Description: A guided, air-to-ground missile designed to take out tactical targets such as tanks, trucks, and ships. The missile gives the pilot a stand-off capability (the ability to fire at a target from a distance with a high probability of hitting the target), reducing the risk to the pilot and his aircraft. Once launched the AGM-65 will guide itself to the target, a capability which allows the pilot to immediately take evasive maneuvers or attack another target. Many aircraft that employ the Maverick can carry as many as six missiles at a time giving the pilot the capability to engage multiple targets on one mission. The Maverick can operate at tree-top level or at high altitudes and can kill a target as close as a few thousand feet or more than 17 miles distant. Built on the modular concept, three different seekers (television, imaging infrared, and laser) and two warheads (a 125-pound shaped charge and a 300-pound penetrator) attach to a common rocket motor section to produce different models of the missile. The Maverick played an important role in defeating Iraqi armor during Operation Desert Storm.

Employment Considerations: To hit long-range targets the Maverick needs a medium altitude launch.

The Maverick A and B models use television guidance systems which need daylight and good weather to operate effectively. Imaging infrared guidance systems used in later models overcome these limitations.

The Maverick models utilizing the 125-pound warhead (models A, B, and D) are typically used to destroy targets such as tanks. To destroy fortified bunkers and similar targets, pilots use the 300-pound warhead (models E, G, and K). The Navy uses the F model, which has a 300-pound warhead and an

infrared seeker, to attack ships.

General Characteristics:
Speed: 715 mph (.9 Mach)
Range: More than 17 miles
Length: 8 feet 2 inches
Diameter: 12 inches
Weight: 462 pounds (AGMM-65A/B)
485 pounds (AGM-65D)
804 pounds (AGM-65F)
670 pounds (AGM-65G)
793 pounds (AGM-65K)
Wingspan: 2 feet 4 inches
Warhead: The Maverick uses two different warheads – a 125-pound shaped charge with a contact fuze and a 300-pound penetrator warhead with a delayed fuze that allows the warhead to penetrate the target before exploding. The AGM-65 models A, B, and D use the 125-pound shaped charge warhead, and the E, F, G and K models use the 300-pound penetrator warhead. The 125-pound shaped charge contains 80 pounds of Comp B explosive, and the 300-pound penetrator warhead contains 80 pounds of PBX explosive.
Guidance System: The pilot employing the AGM-65A/B selects the missile he wants to launch causing its gyro to spin up to speed. He then presses the uncage switch to remove the protective cover from the missile nose. A video picture of what the guidance system sees then appears on a small monitor in the cockpit. The pilot uses the monitor picture to select his target by centering cross hairs on it, and then launches the missile. Upon launch the missile automatically homes on its target. The D, F, and G models operate much the same as the A and B models but use an imaging infrared system which allows their use at night and in adverse weather. The Maverick E model guides on a laser designator. The missile seeker searches a sector seven miles across and more than ten miles to its front. If the seeker loses its laser target designation it goes ballistic and the warhead becomes inoperable.
Control: Four long-cord delta wings attached to the missile's cylindrical body and hydraulically operated flippers mounted near the tail control the missile's flight.
Propulsion: The Maverick uses the Thiokol TX-481 solid-propellant rocket

motor to propel the warhead to its target.
Cost: The price of the Maverick ranges from a low of $17,000 for early models to $180,000 for late models.
Date Deployed: 1972
Launch Aircraft: A-10, AV-8B, F-15E, F-16, F/A-18, F-117, P-3C, and S-3B aircraft. The US Marine Corps' AH-1W and AH-1Z Super Cobra helicopters also employ the Maverick missile.
Contractor: Raytheon

Airmen prepare to load an AGM-65 Maverick missile onto an A-10 Thunderbolt II. *Photo courtesy of the Department of Defense.*

Military Nomenclature: AGM-84-D

Name: Harpoon

Description: An air-launched, anti-ship missile that skims the surface of the water to avoid detection and increase its survivability. The missile uses its own active radar to acquire the target after launch and guide itself to the enemy vessel. This system allows the launch aircraft to fire the missile and then engage another target or take evasive maneuvers.

Employment Considerations: Sea-launched Harpoon missiles employ a terminal pop-up maneuver near the target to counter close-in ship defenses and increase warhead penetration. The air launched Harpoon missile (the AGM-84D) does not use a terminal pop-up maneuver.

The B-52H can carry eight to twelve Harpoon missiles making it a valuable platform for sea control.

General Characteristics:

Speed: 530 mph (about .7 Mach)
Range: More than 70 miles
Length: 12 feet 7 inches
Diameter: 13.5 inches
Weight: 1,145 pounds
Fin Span: 3 feet
Warhead: The AGM-84D carries a 488-pound, high-explosive penetration warhead. The warhead contains 215 pounds of explosive Destex and a contact fuze.
Guidance System: Prior to launch, the missile receives target information from the launch aircraft. After launch, the missile flies a programmed flight to the enemy vessel and then turns on its radar seeker to locate and strike the target.
Control: The guidance system controls missile flight through manipulation of four tail fins. Four fixed fins provide aerodynamic lift.
Propulsion: An air breathing Teledyne Turbojet engine producing 660 pounds of thrust powers the AGM-84D. The turbojet uses JP-10 fuel.
Unit Cost: $720,000
Date Deployed: 1979

Launch Aircraft: B-52H, F-15E, F-16, F/A-18, P-3C, and the S-3B.
Contractor: Boeing

A B-52H armed with AGM-84D Harpoon missiles.
Photo courtesy of the Department of Defense.

Military Nomenclature: AGM-84E/H

Name: Stand-Off Land Attack Missile (SLAM)
Stand-Off Land Attack Missile - Expanded Reponse (SLAM-ER)

Description: A variant of the Harpoon missile designed to attack high-value, land-based targets and ships in port. Intended for use by carrier-based aircraft, the SLAM (AGM-84E) allows US Navy pilots to attack land targets and remain at a safe distance from air defenses. The SLAM can operate in day, night, and adverse weather conditions.

The SLAM-ER (AGM-84H) has twice the range of the SLAM and uses a titanium-cased warhead to increase target penetration. Upgraded software allows the launch pilot to retarget the impact of the missile during the terminal phase of the attack (the last five miles). The Navy plans to convert all SLAM missiles to the SLAM-ER configuration as funding becomes available.

Employment Considerations: Because the pilot can select a specific aimpoint on the target, damage to surrounding areas is minimized. The launch pilot cannot change the aimpoint of the SLAM missile when it closes within five miles of the target (a deficiency corrected in the design of the SLAM-ER).

General Characteristics:

Speed: 530 mph (about .7 Mach)
Range: More than 70 miles (SLAM)
More than 150 miles (SLAM-ER)
Length: 14 feet 8 inches
Diameter: 13.5 inches
Weight: 1,385 pounds
Wing Span: 3 feet
Warhead: The SLAM carries a 500-pound, high-explosive warhead. The SLAM-ER delivers a titanium-cased, 500-pound, high-explosive warhead designed to increase target penetration.
Guidance System: The SLAM has discarded the Harpoon guidance and seeker section and replaced it with the Walleye optical guidance system, added a Global Positioning System (GPS) receiver, and a Maverick data-link. Using components from proven guidance systems allowed the US Navy to field the

missile faster than normally possible. During flight, the GPS receiver updates the missile's navigation system and keeps the SLAM's imaging infrared seeker pointed at the target. When the imaging infrared seeker goes active, it sends a video image back to the launch aircraft. The pilot or bombardier/navigator uses a monitor in the cockpit to select an aimpoint on the target allowing a precision strike.

Control: : The guidance system controls missile flight through manipulation of four tail fins. A pair of deployable wings more than double the range of the SLAM-ER compared to its older sibling the SLAM.

Propulsion: An air breathing Teledyne Turbojet engine producing 660 pounds of thrust powers the AGM-84D. The turbojet runs on JP-10 fuel.

Unit Cost: $720,000 (SLAM)
$500,000 (SLAM-ER)

Deployed Date: 1990 (SLAM)
1999 (SLAM-ER)

Launch Aircraft: F/A-18, P-3C, and the S-3B.

Contractor: Boeing

Aviation ordnancemen load an AGM-84E Standoff Land-Attack Missile onto the wing of an F/A-18C Hornet.
Photo courtesy of The Department of Defense.

Military Nomenclature: AGM-86B/C/D

Name: Air Launched Cruise Missile (ALCM)
Conventional Air Launched Cruise Missile (CALCM)

Description: The ALCM (AGM-86B) gives the B-52H and B-1B bombers a long-range, standoff weapon that can accurately deliver nuclear warheads at distances in excess of 1,500 miles. To give the bombers the ability to launch very accurate conventional attacks, the Air Force updated the ALCM's guidance system and replaced the nuclear warhead with a conventional blast and fragmentation warhead to create the CALCM (AGM-86C). A variant of the CALCM, the AGM-86D uses a unitary penetrating warhead to destroy buried and reinforced targets such as command bunkers.

Employment Considerations: The long range of the AGM-86 allows the launching aircraft to remain well outside of enemy air defenses.

The B-52H can carry 20 AGM-86B/C cruise missiles, allowing the bomber to launch large numbers of missiles and overwhelm enemy air defenses.

The missile's small size and ability to fly at low altitudes make the AGM-86 hard to detect on radar.

General Characteristics:

Speed: 550 mph (ALCM) (.7 mach)
High subsonic (CALCM)
Range: More than 1,500 miles (ALCM)
700 miles (CALCM)
Length: 20 feet 9 inches
Diameter: 24.5 inches
Weight: 3,150 pounds
Wingspan: 12 feet
Warhead: : The AGM-86B delivers a W-80-1 variable-yield thermonuclear warhead. Weighing a mere 300 pounds and measuring about 14 inches in diameter and 31 inches in length, the W-80-1 warhead can produce an explosion between 5 Kt and 150 Kt. The AGM-86C can carry either a 2,000 pound or 3,000 pound conventional blast and fragmentation warhead. To destroy

buried and hardened targets such as command and control bunkers, the AGM-86D employs a unitary penetrating warhead.

Guidance System: : The AGM-86B uses an Inertial Navigation System (INS) aided by Terrain Contour Matching (TERCOM) to strike the target. An INS uses gyroscopes and accelerometers (instruments which detect motion) to determine changes in relative positions. The drift inherent in an INS is too high to allow its use as the sole guidance system in the AGM-86B, so the missile uses a TERCOM system to make corrections to the INS system. The AGM-86B's TERCOM system compares the elevation of the terrain it flies over with the electronic maps it has stored in its software. This comparison allows TERCOM to determine the position of the missile and send that information to the INS which makes any needed course corrections. The AGM-86C/D uses an INS as well, but obtains course corrections from an onboard GPS to obtain pinpoint accuracy.

Control: To obtain aerodynamic flight, the AGM-86 uses small wings and horizontal stabilizers controlled by an onboard computer.

Propulsion: A Williams Research Corporation F-107-WR-10 turbofan engine producing 600 pounds of thrust powers both the ALCM and CALCM.

Unit Cost: $1,000,000 (ALCM)
$1,160,000 (CALCM)

Date Deployed: 1986

Launch Aircraft: The B-52H and B-1B bombers can launch the AGM-86B/C.

Contractor: Boeing

An AGM-86 awaits loading aboard a B-52H Stratofortress.
Photo courtesy of the Department of Defense.

Military Nomenclature: AGM-88

Name: High Speed Anti-Radiation Missile (HARM)

Description: The HARM destroys enemy air defense systems by homing on radar emissions and destroying the emitting radar with blast and fragmentation. Once launched, the missile needs no further inputs from the aircrew and guides itself to the target.

Employment Considerations: Since the HARM needs no input from the launch aircraft once fired, the aircrew can launch and leave the missile – a vital feature when trying to suppress enemy air defenses, a particularly dangerous mission.

The launch aircraft cannot steer the HARM and the HARM cannot discern friend from foe. Since many nations now friendly to the United States use Soviet-era radar and in multinational operations employ these systems, the situation often arises where the same radars appear in enemy and friendly areas. The aircrew is the key element in preventing fratricide in these situations.

General Characteristics:

Speed: More than 760 mph (more than Mach 1)
Range: More than 30 miles
Length: 13 feet 8 inches
Diameter: 10 inches
Weight: 800 pounds
Wingspan: 3 feet
Warhead: The HARM's 143.5-pound warhead contains approximately 45 pounds of PBXC-116 explosive and thousands of pre-formed metal fragments. The A and B models contain 25,000 steel fragments and the C model contains 12,845 tungsten fragments. To determine when to detonate, the missile employs a proximity fuze that emits pulses of laser light. When the fuze senses the return of a laser beam it knows it has closed within lethal range of the target and explodes. The missile can also explode on contact.
Guidance System: The CP-1001B/C HARM Command Launch Computer (CLC) receives target data from the AGM-88 and the launch aircraft's avionics. After processing the data it presents the result on a display in the cockpit.

Prior to missile launch, the aircrew can select one or three engagement modes: self-protect mode (this mode instructs the HARM to seek out missile launch radars), target of opportunity mode (seeks out emitters that go active), and pre-briefed mode (seeks out emitters on specific frequencies). Once launched, the missile needs no further input from the aircrew and uses its own passive seeker to home on the target.

Control: Four wings controlled by electro-mechanical actuators steer the missile. Four tail fins give the missile aerodynamic stability during flight.

Propulsion: A dual-thrust rocket motor that burns a low-smoke propellant powers the AGM-88. The Thiokol motor produces 64,000 pounds of thrust per second.

Unit Cost: $284,000

Date Deployed: 1984

Launch Aircraft: F-15E, F-16CJ, F/A-18, and the EA-6B.

Contractor: Raytheon

Ordnance personnel prepare to load an AGM-88 on an aircraft weapons pylon.
Photo courtesy of the Department of Defense.

Military Nomenclature: AGM-114

Name: Heliborne, Laser, Fire and Forget Modular Missile System (Hellfire)

Description: The AGM-114 gives attack helicopters and slow-moving fixed-wing aircraft the ability to destroy heavy armor (the Hellfire can defeat any known tank in the world), bunkers, ships, and other helicopters. The aircrew guides the missile by projecting a laser spot onto the target. To strike the designated target, the missile homes on the laser spot. The Hellfire will also guide on a laser spot projected onto the target by ground observers or other aircraft, enabling the missile to be used in a number of tactical engagement modes. The Longbow Hellfire missile uses the Longbow fire control radar system to locate targets.

The Central Intelligence Agency (CIA) has armed the Predator Unmanned Aerial Vehicle (UAV) with the Hellfire missile and successfully destroyed ground targets in Afghanistan. The armed Predator uses laser-guided versions of the Hellfire missile.

Employment Considerations: The AGM-114 cannot engage at ranges less than 500 meters.

Low cloud ceilings, fog, and battlefield smoke can scatter lasers and prevent target designation.

Using the Longbow radar, the AH-64D Apache helicopter can fire and forget the Hellfire and engage in adverse weather conditions (lasers can scatter in smoke, fog, and similar obscurants).

The Hellfire has proved crucial in attacking targets in built-up areas. The anti-armor weapon punches through buildings before exploding, which reduces collateral damage.

General Characteristics:

Speed: 950 mph (more than mach 1)
Range: 4.3 miles (AGM-114A/B/C/F)
4.8 miles (AGM-114K/L)
Length: 5 feet 3.5 inches (AGM-114A/B/C/K0
5 feet 9 inches (AGM-114F)

5 feet 8 inches (AGM-114)

Diameter: 7 inches

Weight: 100.8 pounds (AGM-114A/B/C/K)
105.6 pounds (AGM-114K anti-ship variant)
107.1 pounds (AGM-114F)
110-2 pounds (AGM-114L)

Wingspan: 28 inches

Warhead: To penetrate armor, concrete bunkers, and similar fortifications, the AGM-114A Hellfire uses a 17.6-pound warhead containing a shaped charge that explodes on impact. The shaped charge focuses its explosive power into a small stream that cuts through armor and other hardened structures.

The AGM-114F/L incorporates a tandem warhead designed to defeat reactive armor. Reactive armor consists of explosive modules placed on the surface of traditional armor that explode outward when struck by a shaped charge. The outward explosion blunts the power of the shaped charge. To defeat reactive armor, the AGM-114F/L has a forward warhead module between the seeker and main warhead that contains a small explosive charge that sets off the reactive armor module. The main warhead then fires and penetrates the traditional armor.

The AGM-114K uses a 27.5-pound warhead to destroy ships and hard targets using blast and fragmentation. It explodes on impact.

Guidance System: The aircrew guides the missile by projecting a laser spot onto the target. To strike the designated target, the missile homes on the laser spot. The Hellfire will also guide on a laser spot projected onto the target by ground observers or other aircraft.

The Longbow Hellfire missile uses the Longbow fire control radar system to locate targets. Once the Apache helicopter's Longbow AN/APG-78 Fire Control Radar (FCR) acquires the target, it feeds engagement parameters to the missile's active MilliMeter-Wave (MMW) radar and inertial guidance systems.

When engaging a moving target or a stationary target at close range, the missile's MMW radar (located in the nose of the missile) locks onto the target before launch. Once launched, the MMW radar feeds updates to the missile's guidance system and flies it to the target. Against long-range stationary targets, the crew launches the Hellfire in Lock On After Launch (LOAL) mode. After launch, the missile's inertial guidance steers the missile in the direction of

the target while the missile's MMW radar actively seeks it out. Once the radar acquires the target, it sends updates to the missile's guidance system and flies the Hellfire to the target.

Control: The Hellfire nose section has four small clipped delta stabilizing fins in a cruciform configuration, and the rear third of the missile has four in-line, wide-chord, short-span fixed wings with control fins at their trailing edges to achieve aerodynamic stability and maneuver during flight.

Propulsion: A single-thrust, low-smoke rocket motor that burns a solid propellant powers the AGM-114.

Unit Cost: The price of the Hellfire ranges from less than $40,000 to $57,000.

Date Deployed: 1982

Launch Aircraft: AH-1W, AH-64, MD-530, OH-58, Predator UAV, SH-60B/HH-60H, and the UH-60.

Contractor: Boeing and Lockheed Martin

A SH-60 Seahawk helicopter fires an AGM-114 Hellfire missile.
Photo courtesy of the Department of Defense.

Military Nomenclature: AGM-119
Name: Penguin

Description: The AGM-119 is a helicopter-launched anti-ship missile. A "fire and forget" weapon, the launch helicopter can engage more than one ship at a time. The Penguin's guidance system can also identify and target the

waterline of an enemy vessel. The missile's 265-pound warhead has a delayed-action fuze that allows it to penetrate the side of a ship before detonation. While devastating to small vessels, the Penguin can also sink medium-sized vessels and surfaced submarines.

Employment Considerations: The long range of the Penguin allows the launch aircraft to remain at a safe distance from the target vessel.

The "fire and forget" capability of the missile allows the launch aircraft to engage several vessels at the same time.

General Characteristics:

Speed: About 888 mph (more than Mach 1)
Range: About 22 miles
Length: 9 feet 9 inches
Diameter: 11 inches
Weight: 850 pounds
Wingspan: 4 feet 8 inches

Warhead: The AGM-119 is equipped with a 265-pound, Semi-Armor-Piercing (SAP) warhead derived from the Bullpup missile. It contains 110 pounds of high explosive and a delayed-action fuze that allows the missile to penetrate the side of the ship before detonation. The missile's guidance system targets the enemy vessel's waterline where the warhead can inflict major damage on medium-sized marine vessels.

Guidance System: The AGM-119 is a "fire and forget" missile. After launch, the missile uses inertial guidance to establish its initial flight path. Inertial guidance uses gyroscopes and accelerometers (instruments which detect motion) to determine changes in relative positions. The missile maintains its altitude with pulsed-laser. As it nears the target, the Penguin's passive infrared seeker searches for the enemy vessel (target data is preset before launch). Infrared seekers search for heat sources. After the missile locates the target it switches to track mode. When in track mode, the seeker uses an imaging process to map the target against the background of the sea (this allows the missile to locate the waterline of the vessel). The missile targets the waterline.

Control: The Penguin missile employs four folding wings and four canards to maintain aerodynamic flight.

Propulsion: A solid-propellant, two-stage rocket motor powers the AGM-119.

Unit Cost: $1.57 million
Date Deployed: 1994
Launch Aircraft: SH-60B/F
Contractor: Kongsberg Vaapenfabrikk

A SH-60 Seahawk helicopter fires an AGM-119 Penguin missile.
Photo courtesy of the US Navy.

Military Nomenclature: AGM-129A

Name: Advanced Cruise Missile

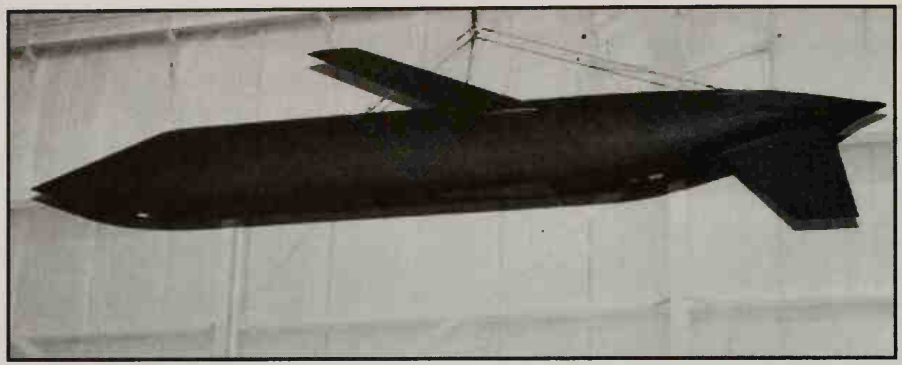
Description: An air-launched cruise missile with stealth capabilities, the AGM-129A carries a nuclear warhead into areas defended by advanced air-defense systems.

Employment Considerations: The slow speed of a conventional cruise missile combined with an external shape that makes it observable to radar increases its vulnerability when penetrating a heavily defended area. The

Advanced Cruise Missile uses stealth characteristics to reduce its radar, infrared, and visual signature and increase its survivability in areas defended by advanced air-defense systems.

General Characteristics:

Speed: Less than 760 mph (less than mach 1)
Range: 1,738 miles
Length: 20 feet 10 inches
Diameter: 27.75 inches
Weight: 3,600 pounds
Wingspan: 10 feet 2 inches
Warhead: The AGM-129 delivers a W-80-1 variable-yield thermonuclear warhead. Weighing a mere 300 pounds and measuring about 14 inches in diameter and 31 inches in length, the W-80-1 warhead can produce an explosion between 5 Kt and 150 Kt. The missile can also be fitted with conventional warheads if needed.
Guidance System: The missile uses an Inertial Navigation System (INS) aided by Terrain Contour Matching (TERCOM) to obtain accuracy within 100 to 300 feet of the target. An INS uses gyroscopes and accelerometers (instruments which detect motion) to determine changes in relative positions. The drift inherent in an INS is too high to allow its use as the sole guidance system in the AGM-129, so the missile uses a TERCOM system to make corrections to the INS system. The AGM-129's TERCOM system uses a laser sensor to compare the elevation of the terrain it flies over with the electronic maps it has stored in its software. This comparison allows TERCOM to determine the position of the missile and send that information to the INS which makes any needed course corrections. It is believed that existing missiles have also received GPS receivers to further improve accuracy.
Control: To maintain aerodynamic flight, the missile uses forward-swept wings and tailplanes designed to reduce their radar signature.
Propulsion: A Williams F112-WR-100 turbofan engine producing 732 pounds of thrust powers the AGM-129.
Unit Cost: $1,000,000
Date Deployed: 1990
Launch Aircraft: B-52H
Contractor: Raytheon



The AGM-129A incorporates stealth characteristics.
Photo courtesy of the U.S. Air Force Museum.

Military Nomenclature: AGM-130

Name: Powered Standoff Weapon

Description: A powered derivative of the GBU-15 glide bomb, the AGM-130 consists of a 2,000-pound bomb, a target detector, and mechanical control fins. Two versions of the AGM-130 remain in the inventory, the A model uses the MK-84 warhead (a 2,000-pound blast and fragmentation bomb) and the C model uses the BLU-109 penetration warhead. A rocket motor propels the weapon and gives it greater range than the GBU-15, which increases the survivability of the launch aircraft.

Employment Considerations: The ability of the AGM-130 to fly to its target under INS/GPS control reduces the workload on the weapon system officer (WSO).

The AGM-130's horizontal target attack (HTA) mode gives the weapon the ability to strike buried bunkers and the roofs of buildings.

Equipped with a radar altimeter, the missile can approach a target from a height of 200 feet or as high as 30,000 feet above the ground and the WSO can adjust the altitude of the missile at any time to evade threats to the missile or bad weather.

Heavy fog and other low weather can make laser guided munitions

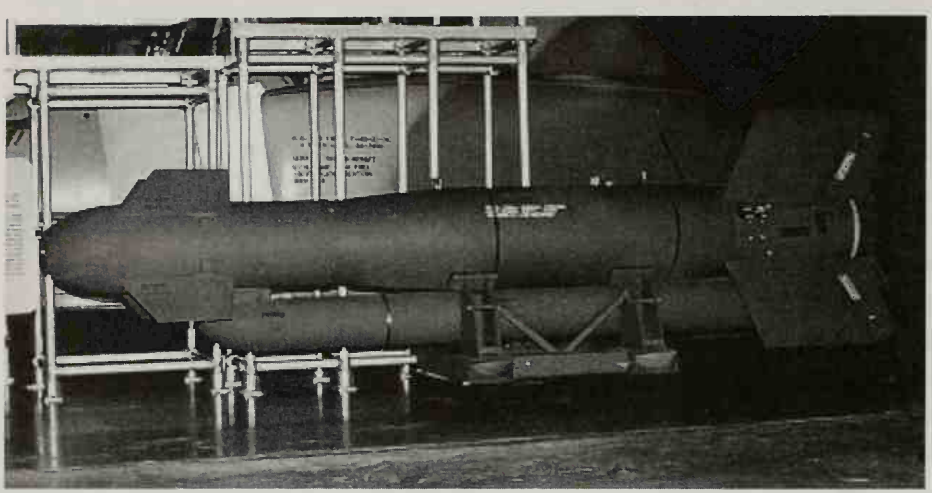
unusable, but the AGM-130 can operate in inclement weather and continue to provide attacking aircraft standoff capability (the ability to attack a target while remaining at a safe distance), which reduces the risk to pilots when attacking heavily defended areas and the number of support aircraft needed to accomplish the mission.

The missile can also strike slow moving targets.

General Characteristics:

Speed: Classified
Range: More than 40 miles
Length: 12 feet 10.5 inches
Diameter: 18 inches
Weight: 2,917 pounds
Wingspan: 4 feet 11 inches
Warhead: The AGM-130 is armed with a MK-84 (a 2,000-pound, blast/fragmentation bomb) or a BLU-109 (a 2,000-pound bomb designed to penetrate hard targets).
Guidance System: The launch aircraft's WSO can lock onto the target before missile launch and allow the AGM-130 to guide itself to the target, or he can manually steer the missile. Normally, the pilot will fly the aircraft to a pre-briefed launch position and the WSO will launch the missile when he receives seeker signals. After launch, the weapon travels to the target using its inertial navigation system aided by a global positioning satellite system. The WSO can control the missile at any time through a two-way communications system (the AN/AXQ-14 Data Link System). Inside the cockpit, the WSO has a display that shows him the image acquired by the television or infrared imaging sensor in the bomb's nose. When the weapon transitions into the terminal phase of the flight (15 seconds before impact), the WSO locks the seeker onto the target or takes control of the missile and manually guides it to the impact point. The AGM-130 can also be launched from one aircraft and guided by another.
Control: The missile uses strakes and small wings to obtain flight stability.
Propulsion: A sold propellant rocket motor thrusts the AGM-130 towards its target.
Unit Cost: $652,214 (TV or IR guidance with MK-84 warhead)
$653,018 (TV or IR guidance with BLU-109 warhead)

Date Deployed: 1994
Launch Aircraft: F-15E and the F-16.
Contractor: Boeing



A rocket motor (mounted at the bottom) powers the AGM-130 to the target.
Photo courtesy of the U.S. Air Force Museum.

Military Nomenclature: AGM-142

Name: HAVE NAP (The Air Force designated the AGM-142 the Raptor, but when the F/A-22 Advanced Technology Fighter took the name, the Air Force re-designated the missile the HAVE NAP, which was the name of the program designed to improve the non-nuclear capabilities of the B-52.)

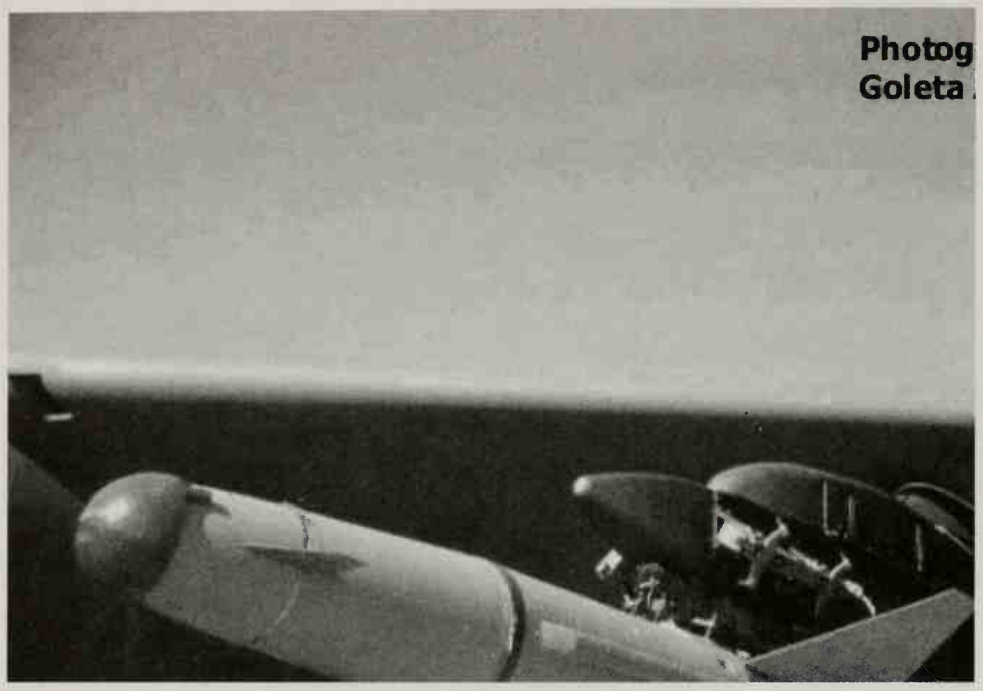
Description: A standoff cruise missile designed to give the B-52H bomber a conventional precision strike capability against high value, fixed targets such as power plants, refineries, and radar sites. Built on the modular concept, the AGM-142 has two warheads (a 750-pound blast and fragmentation warhead and a 770-pound penetration warhead) and two seekers (television and imaging infrared) that allow four missile configurations.

Employment Considerations: The TV seeker limits the missile's use to daylight hours.

An Israeli-built weapon, the missile has potential negative political implications if used against an Arab country.

General Characteristics:

Speed: Supersonic
Range: More than 50 miles
Length: 15 feet 10 inches
Diameter: 21 inches
Weight: 3,000 pounds
Wingspan: 6 feet 6 inches
Warhead: The AGM-142 employs two different warheads – a 770-pound blast and fragmentation warhead and a 750-pound I-800 penetration warhead. The blast and fragmentation warhead actually contains 330 pounds of explosive. The penetration warhead contains 170 pounds of explosive.
Guidance System: The Raptor uses either a television or an imaging infrared seeker in its guidance system. Both seekers display a picture on a monitor in the launch aircraft which allows the weapon operator to select an aimpoint using a datalink command channel. Often referred to as a "man-in-the-loop" system, this type of guidance system allows a person to select the actual spot where the missile will strike the target.
Control: To achieve aerodynamic flight, the missile uses canards, wings, and fins. Hydraulically powered tail surfaces give the missile flight control.
Propulsion: A solid propellant rocket motor rapidly accelerates the missile to supersonic speeds.
Unit Cost: $1.2 million
Date Deployed: 1992
Launch Aircraft: B-52H and the F-15E.
Contractor: Rafael/Lockheed Martin



A rocket motor (mounted at the bottom) powers the AGM-130 to the target. AGM-142s mounted on the weapons pylon of a B-52H. *Photo courtesy of Brain Lockett and the Goleta Air & Space Museum.*

Military Nomenclature: AGM-154

Name: Joint Stand-Off Weapon (JSOW)

Description: A standoff glide weapon with a modular design that allows it to carry several different submunitions, unitary warheads, or non-lethal payloads. The AGM-154A carries combined effects bomblets designed to attack area, personnel, and soft targets. The AGM-154B variant dispenses smart submunitions designed to destroy tanks and other armored vehicles. Used by the US Navy, the AGM-154C delivers a BLU-111, a 500-pound bomb designed to penetrate hard targets such as ships or concrete bunkers. It has a reduced radar signature to increase its survivability en route to the target.

Employment Considerations: The JSOW can operate day or night and

in adverse weather conditions, although high winds can affect the accuracy of the AGM-154.

The U.S. military measures bomb accuracy using a calculation known as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The AGM-154 has a CEP of ten feet.

General Characteristics:

Range: 13 miles if released at low altitude; 35 miles if released at high altitude.
Length: 133 feet 4 inches
Diameter: 16 inches to 22 inches
Weight: Varies between 1,065 pounds to 1,500 pounds depending upon the payload and sensor combinations used.
Wingspan: 8 feet 10 inches
Warhead: The AGM-154A carries a cluster munition warhead consisting of 145 BLU-97/B submunitions. Each bomblet has a shaped charge to defeat light armor, a fragmenting case to destroy material and personnel, and a zirconium ring for incendiary effects. The AGM-154B also carries a cluster munition consisting of six BLU-108/B submunitions. Each submunition releases four projectiles with infrared sensors designed to seek out the heat of tank or vehicle engines. When the sensor detects a heat source, it detonates the projectile which sends a shaped charge capable of penetrating reinforced armor into the target.

Guidance System: The JSOW uses an inertial and global positioning system (GPS/INS) to fly a preprogrammed flight to the target. An INS uses gyroscopes and accelerometers (instruments which detect motion) to determine changes in relative positions. The drift inherent in an INS is too high to allow its use as the sole guidance system in the AGM-154, so the missile uses a GPS system to make corrections to the INS system. During flight, the GPS receiver updates the weapon's navigation system and keeps the AGM-154's imaging infrared seeker pointed at the target. When the imaging infrared seeker goes active, it sends a video image back to the launch aircraft. The pilot or bombardier/navigator uses a monitor in the cockpit to select an aimpoint on the target allowing a precision strike. Often referred to as a "man-in-the-loop"

system, this type of guidance system allows a person to select the actual spot where the missile will strike the target.

The crew can also launch and leave the weapon. It will fly itself to the target and strike preprogrammed GPS coordinates.

Propulsion: None

Unit Cost: Varies from about $250,000 to $660,000.

Date Deployed: 1998

Launch Aircraft: F-15E, F-16, F/A-18, AV-8B, B-1B, B-52H, and the P-3C aircraft.

Contractor: Raytheon

Ordnancemen move a JSOW aboard the USS Harry S. Truman. *Photo courtesy of the U.S. Navy.*

Military Nomenclature: AGM-158

Name: Joint Air-to-Surface Standoff Missile (JASSM)

Description: An air-launched stealth cruise missile designed to launch outside enemy air defenses and autonomously fly a low-level circuitous route to the target. These design features increase both delivery aircraft and missile survival in heavily defended areas. To destroy the target, the missile carries a 1,000-pound warhead capable of penetrating hard targets. The AGM-158 is in low rate production.

Employment Considerations: Precision guided munitions have made bomb damage assessment more difficult. With cruise missiles and GPS satellite-guided bombs the weapons of choice, no cockpit videos exist to aid in early bomb damage assessment. To verify the effectiveness of the strike, command-

ers must schedule an unmanned aerial vehicle, reconnaissance aircraft, or spy satellite to overfly the target. These limited resources are not always available, leading to re-strikes of previously destroyed targets and no second strikes on targets believed destroyed but in reality still active. The AGM-158 has a built-in bomb damage assessment mechanism and can transmit its status and location until impact with the target.

The U.S. military measures bomb accuracy using a calculation known as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The AGM-158 has a CEP of eight feet.

General Characteristics:

Speed: Subsonic
Range: More than 115 miles
Length: 14 feet
Diameter: 1 foot 6 inches
Weight: 2,250 pounds
Wingspan: 7 feet 11 inches
Warhead: The AGM-158 destroys targets with a 1,000-pound WDU-42/B hard target warhead filled with AFX-757, an insensitive high explosive. The use of an insensitive high explosive delays detonation in fuel fires (a common occurrence when an aircraft crashes).
Guidance System: The JASSM uses an inertial and global positioning system (GPS/INS) to fly a preprogrammed flight to the target. An INS uses gyroscopes and accelerometers (instruments which detect motion) to determine changes in relative positions. The drift inherent in an INS is too high to allow its use as the sole guidance system in the AGM-158, so the missile uses a GPS system to make corrections to the INS system. During flight, the GPS receiver updates the weapon's navigation system and keeps the AGM-158's imaging infrared seeker pointed at the target. When the imaging infrared seeker goes active, it sends a video image back to the launch aircraft. The pilot or bombardier/navigator uses a monitor in the cockpit to select on aimpoint on the target allowing a precision strike. Often referred to as a "man-in-the-loop" system, this type of guidance system allows a human to select the actual spot where the missile will strike the target.
Control: After release from the aircraft, thin, swept-back wings with control

surfaces flip out from the AGM-158's airframe. A single vertical tail also assists in the maintenance of aerodynamic flight.

Propulsion: A Teledyne CAE J402-CA-100 turbojet engine, which produces 680 pounds of thrust propels the AGM-158 at subsonic speed.

Unit Cost: $700,000

Date Deployed: 2002

Delivery Aircraft: B-1B, B-2, B-52H, F-15, F-16, F/A-18, F-117, P-3C, and the S-3B.

Contractor: Lockheed Martin

An F-16 conducts a flight test with an AGM-158 Joint Air-to-Surface Standoff Missile mounted under its wing. *Photo courtesy of the USAF.*

Chapter 3: Unguided Munitions

MILITARY NOMENCLATURE: BLU-82B

NAME: 15,000 lb. General Purpose Bomb

Description: The largest conventional bomb in existence, the BLU-82 requires a high-altitude release. Designed to create instant helicopter landing zones in the jungle, post-Vietnam the bomb has served as an anti-personnel weapon. The weapon deploys from the aircraft via a cradle and cargo extraction parachute, which later separates from the bomb. A bomb stabilization parachute deploys and orients the bomb to the ground and slows its descent to 340 feet per second. Using a 38-inch fuze extender, the BLU-82 explodes just above ground level to maximize its destructive effect. At ground zero, the weapon produces an overpressure of 1,000 pounds per square inch.

Employment Considerations: Big and heavy, the BLU-82 requires delivery from a MC-130E/H aircraft, a C-130 transport converted to support special operations missions.

The blast effects of this weapon require a minimum release altitude of 6,000 feet. If dropped below that altitude, the blast could damage the delivery aircraft.

The blast of the BLU-82 makes it extremely effective at destroying bunker complexes and other defensive fortifications. Experience has shown that the bomb has a strong psychological effect on the enemy.

The bomb will clear an LZ (helicopter landing zone) about 260 feet in width in jungle terrain. It has also been used to clear minefields but with less success.

Combat operations in Iraq and Afghanistan have seriously depleted the BLU-82 inventory. The Air Force plans to replace the BLU-82 with the Massive Ordnance Air Blast (MOAB) bomb. The MOAB weighs 21,500 pounds (6,500 pounds more than the BLU-82) and uses GPS guidance to

obtain greater accuracy than the unguided BLU-82.

General Characteristics:
Range: Varies depending on release altitude.
Length: 11 feet 9.6 inches
Diameter: 4 feet 6 inches
Weight: 15,000 pounds
Warhead: The warhead is a large cylinder with a conical aerodynamic nose filled with 12,600 pounds of GSX, a slurry explosive consisting of ammonium nitrate, aluminum powder, and polystyrene. A 38-inch fuze extender mounted on the nose explodes the bomb just above ground level to maximize its destructive effect and prevent the bomb from digging a crater.
Guidance System: : The MC-130 crew uses onboard navigational and positioning equipment to deliver the bomb to the target area. Ground and aerial radar control stations can also guide the MC-130 crew to the bomb release point. Once released, the BLU-82 falls unguided toward the target area.
Control: A parachute orients the bomb toward the ground and slows its descent. This ensures that the fuze extender will explode the bomb above ground level and allows the delivery aircraft time to escape the blast.
Propulsion: None
Unit Cost: $27,318
Date Deployed: 1970
Launch Aircraft: MC-130E/H
Contractor: Inventory

The BLU-82 contains 12,600 pounds of explosive.
Photo courtesy of the U.S. Air Force Museum.

Military Nomenclature: BLU-107B

Name: Durandal

Description: This weapon craters enemy runways. To operate effectively, the BLU-107 requires a low-altitude release. Once released from the aircraft, the Durandal deploys a parachute to slow its descent and obtain the proper impact angle (a nose-down attitude). The parachute releases as the weapon nears the ground. After the parachute release, the BLU-107's rocket motor fires, launching the warhead into the runway. A delay fuze allows the warhead to penetrate up to 16 inches of reinforced concrete before detonation. The resulting explosion creates a 200-square-meter crater.

Employment Considerations: The BLU-107 requires a low-level release exposing the delivery aircraft to antiaircraft fire.

While the BLU-107 requires a low-level release, it needs a minimum release altitude of 300 feet above ground level (AGL) to properly deploy its parachute and orient itself to the runway.

If the pilot drops the weapon too far down the runway, the crater may not prevent enemy aircraft from using the strip.

General Characteristics:

Speed: Varies depending on release altitude.
Length: 8 feet 2 inches
Diameter: 8.8 inches
Weight: 450 pounds
Warhead: The BLU-107 uses a 330-pound penetrator warhead (a penetrator warhead has a slim shape and a thick nose and side walls that allow it to survive impact and penetration of hardened surfaces and structures). The warhead contains 35 pounds of TNT and uses a delay fuze, which allows maximum penetration of the target before detonation.
Guidance System: Ballistic
Control: After release from the aircraft, fins give the weapon flight stability. A parachute then deploys to retard the weapon and orient its nose toward the ground. As the weapon nears the ground, the parachute releases the weapon and a rocket motor fires and powers the warhead into the concrete of the runway.

Propulsion: Rocket boosted after parachute release.
Unit Cost: $2,126.00
Date Deployed: 1988
Delivery Aircraft: F-15E and the F-16.
Contractor: European Aeronautic Defense and Space Company.

The BLU-107 craters runways.

Military Nomenclature: BLU-109

Name: 2,000 lb. Hard Target Warhead

Description: A 2,000-pound bomb designed to penetrate hard targets. Built of one-inch thick, high-grade steel, the BLU-109 has a slender shape to help it punch through hardened structures. To survive penetration, the bomb employs a tail-mounted, time-delay fuze. The time delay allows the BLU-109 to plunge well into its target before denotation. The BLU-109 acts as a warhead only and is always mounted to a laser-guidance or GPS-guidance kit or fitted with an Imaging Infrared Radiation (IRR) seeker and a set of aerodynamic control surfaces to form a precision-guided munition.

Employment Considerations: If penetration warheads strike the target at an angle they tend to bounce off the target, a characteristic often referred to as the J-hook effect.

General Characteristics:

Range: The BLU-109 is always used as a warhead and mated with a laser guidance or GPS-guidance kit or fitted with an Imaging Infrared Radiation (IRR) seeker and a set of aerodynamic control surfaces to form a precision guided munition.

Length: 8 feet 2.5 inches
Diameter: 1 foot 2.5 inches
Weight: 1,950 pounds
Warhead: The BLU-109 has a one-inch thick case made of high-strength steel designed to penetrate hardened structures. The bomb contains 550 pounds of Tritional explosive and uses a tail-mounted, time-delay fuze to detonate the warhead after penetration. The fuze is attached to the tail to prevent it from being crushed when the bomb punches its way into the target.
Guidance System: The BLU-109 has no guidance capability. It does serve as the warhead for precision guided munitions such as the GBU-10, GBU-15, GBU-24, GBU-31 and the AGM-130. See those weapon systems for their guidance capabilities.
Control: The BLU-109 has no aerodynamic flight control surfaces. It does serve as the warhead for precision guided munitions such as the GBU-10, GBU-15, GBU-24, GBU-31 and the AGM-130. See those weapon systems for their aerodynamic flight control surfaces.
Propulsion: None
Unit Cost: $14,384.78
Deployed Date: 1985
Delivery Aircraft: The BLU-109 serves as a warhead for precision guided munitions, primarily the GBU-10, GBU-15, GBU-24, GBU-31, and the AGM-130. See those weapon systems for the deliver aircraft used to delivery the munitions.
Contractor: Lockheed Martin

The bombs nearest the camera are BLU-109 penetrating bombs pre-positioned for quick loading onto aircraft. *Photo courtesy of the USAF.*

Military Nomenclature: BLU-110

Name: 1,000 lb. General-Purpose Bomb

Description: A MK-83 general-purpose bomb filled with PBXN-109, an explosive less sensitive to heat than traditional explosives. This characteristic increases the time the bomb can spend in a fuel fire before explosion, an important feature aboard an aircraft carrier. The re-designation as BLU-110 alerts ordnance personnel to the bomb's thermal protection. Developed in the 1950s, the MK-80 series of general-purpose bombs have an aerodynamic, cylindrical shape that reduces drag, an important factor when high-speed aircraft carry bombs hung on their wings. Planners use the BLU-110 against targets vulnerable to blast and explosive effects. It is not designed to penetrate hard targets. Typical targets include troops, artillery emplacements, truck parks, and radars.

Employment Considerations: The optimum release altitude for non-guided bombs is 5,000 feet, which places the delivery aircraft within easy reach of ground fire. To safeguard aircraft and flight crews, American air commanders restrict delivery aircraft to bombing altitudes above 15,000 feet. Since this tactic affects the accuracy of non-guided bombs, planners only use these weapons in areas where there is little chance of civilian casualties or collateral damage.

General-purpose bombs destroy targets through blast and fragmentation. When a bomb explodes, the energy released compresses the surrounding air. These tremendous overpressures can knock down buildings, destroy machinery, and kill personnel by damaging internal organs. The blast effect will only kill humans for a short distance from the explosion. For example, a 2,000-pound GP bomb will kill a human through blast effect up to 110 feet from the point of detonation. An exploding general-purpose bomb will also create many bomb fragments. These fragments achieve velocities ranging from 5,000 to 9,000 feet per second and will kill personnel and destroy equipment at much greater ranges. Effective against personnel, vehicles, and aircraft, these fragments can kill up to 3,000 feet from the point of detonation regardless of bomb size.

To create craters (used to destroy supply roads, runways, or deny terrain to the enemy), planners can outfit GP bombs with delay fuzes. This

arrangement allows the bomb to penetrate the surface before detonation and results in a large crater. Delay fuzes will also allow a GP bomb to penetrate building roofs before detonation resulting in greater destructive effect to the building.

General Characteristics:

Range: Varies depending on release altitude.
Length: 9 feet 7 inches
Diameter: 1 foot 2 inches
Weight: 1,000 pounds
Warhead: The BLU-110 contains 445 pounds of PBXN-109 explosive. A variety of mechanical (impact) nose and tail fuzes and electrical fuzes (used to explode the bomb in the air above the target) can denote the bomb.
Guidance System: Ballistic
Control: Fin assemblies cause the bomb to fall in a smooth, definite curve toward the target, instead of tumbling through the air. The BLU-110 uses conical, low-drag fins for medium and high-altitude delivery. Retarded fins allow a delivery aircraft to drop the bomb at high-speed and low altitude and escape the blast and fragmentation of the bomb denotation. The BLU-110 uses the BSU-85 high drag tail assembly. The BSU-85 deploys an air-inflated retarder (basically a bag filled with air) to slow the bomb's descent. Retarded fins have the capability to be used in both a retarded and non-retarded mode.
Propulsion: None
Unit Cost: $3,128.83
Date Deployed: 1985
Delivery Aircraft: A-10, F-14, F-15, F-16, and the F/A-18.
Contractor: Inventory

A navy aviation ordnanceman transports two BLU-110 bombs aboard the USS George Washington. *Photo courtesy of the U.S. Navy.*

Military Nomenclature: BLU-111

Name: 500 lb. General-Purpose Bomb

Description: A MK-82 general-purpose bomb filled with PBXN-109, an explosive less sensitive to heat than traditional explosives. This characteristic increases the time the bomb can spend in a fuel fire before explosion, an important feature aboard an aircraft carrier. The re-designation as BLU-111 alerts ordnance personnel to the bomb's thermal protection. Developed in the 1950s, the MK-80 series of general purpose bombs have an aerodynamic, cylindrical shape that reduces drag, an important factor when high-speed aircraft carry bombs hung on their wings. Planners use the BLU-111 against targets vulnerable to blast and explosive effects. It is not designed to penetrate hard targets. Typical targets include troops, artillery emplacements, truck parks, and radars.

Employment Considerations: The optimum release altitude for non-guided bombs is 5,000 feet, which places the delivery aircraft within easy reach of ground fire. To safeguard aircraft and flight crews, American air commanders restrict delivery aircraft to bombing altitudes above 15,000 feet. Since this tactic affects the accuracy of non-guided bombs, planners only use

these weapons in areas where there is little chance of civilian casualties or collateral damage.

General-purpose bombs destroy targets through blast and fragmentation. When a bomb explodes, the energy released compresses the surrounding air. These tremendous overpressures can knock down buildings, destroy machinery, and kill personnel by damaging internal organs. The blast effect will only kill humans for a short distance from the explosion. For example, a 2,000-pound GP bomb will kill a human through blast effect up to 110 feet from the point detonation. An exploding general-purpose bomb will also create many bomb fragments. These fragments achieve velocities ranging from 5,000 to 9,000 feet per second and will kill personnel and destroy equipment at much greater ranges. Effective against personnel, vehicles, and aircraft, these fragments can kill up to 3,000 feet from the point of detonation regardless of bomb size.

To create craters (used to destroy supply roads, runways, or deny terrain to the enemy), planners can outfit GP bombs with delay fuzes. This arrangement allows the bomb to penetrate the surface before detonation and results in a large crater. Delay fuzes will also allow a GP bomb to penetrate building roofs before detonation resulting in greater destructive effect to the building.

General Characteristics:

Range: Vaaries depending on release altitude.
Length: 5 feet 6.2 inches
Diameter: 10.75 inches
Weight: About 500 pounds (the weight varies depending on the stablizer used).
Warhead: The BLU-111 contains 192 pounds of PBXN-109 explosive. A variety of mechanical (impact) nose and tail fuzes and electrical fuzes (used to explode the bomb in the air above the target) can denote the bomb.
Guidance System: Ballistic.
Control: Fin assemblies cause the bomb to fall in a smooth, definite curve toward the target, instead of tumbling through the air. The BLU-111 uses conical, low-drag fins for medium and high-altitude delivery. Retarded fins allow a delivery aircraft to drop the bomb at high-speed and low altitude and escape

the blast and fragmentation of the bomb denotation. The BLU-111 uses two types of retarded fins: the MK-15 Snakeye, which deploys four large plates that slow the bomb's descent, and the BSU-49, which deploys an air-inflated retarder (basically a bag filled with air) to slow the bomb's descent. Retarded fins have the capability to be used in both a retarded and non-retarded mode.

Propulsion: None

Unit Cost: $2,082

Date Deployed: 1985

Delivery Aircraft: A-10, B-1B, B-52H, F-14 F-15, F-16, F/A-18, and the F-117.

Contractor: Inventory

A sailor transports two 500-pound BLU-111s. *Photo courtesy of the U.S. Navy.*

Military Nomenclature: BLU-112

Name: 2,000 lb. General-Purpose Bomb

Description: A MK-84 general-purpose bomb filled with PBXN-109, an explosive less sensitive to heat than traditional explosives. This characteristic increases the time the bomb can spend in a fuel fire before explosion, an important feature aboard an aircraft carrier. The re-designation as BLU-112 alerts ordnance personnel to the bomb's thermal protection. Developed in the 1950s, the MK-80 series of general-purpose bombs have an aerodynamic, cylindrical shape that reduces drag, an important factor when high-speed aircraft carry bombs hung on their wings. Planners use the BLU-112 against targets vulnerable to blast and explosive effects. It is not designed to penetrate hard targets. Typical targets include troops, artillery emplacements, truck parks, and radars.

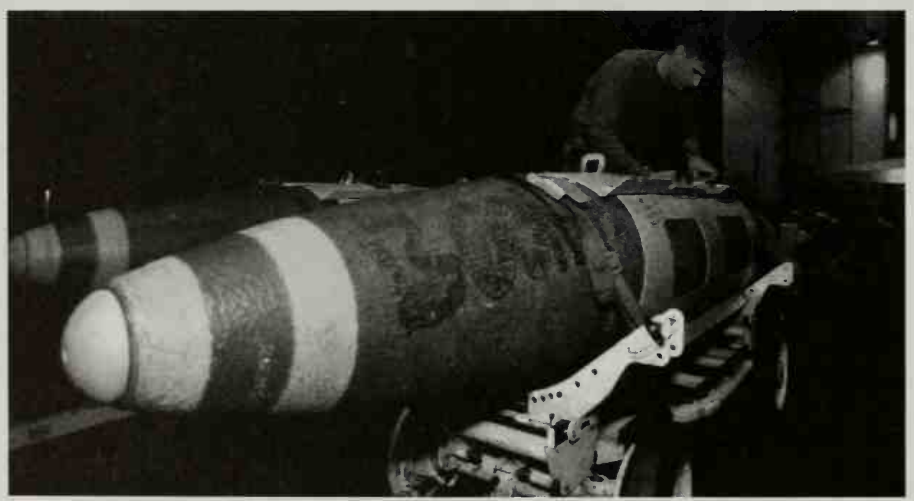
General-purpose bombs destroy targets through blast and fragmentation. When a bomb explodes, the energy released compresses the surrounding air. These tremendous overpressures can knock down buildings, destroy machinery, and kill personnel by damaging internal organs. The blast effect will only kill humans for a short distance from the explosion. For example, a 2,000-pound GP bomb will kill a human through blast effect up to 110 feet from the point of detonation. An exploding general-purpose bomb will also create many bomb fragments. These fragments achieve velocities ranging from 5,000 to 9,000 feet per second and will kill personnel and destroy equipment at much greater ranges. Effective against personnel, vehicles, and aircraft, these fragments can kill up to 3,000 feet from the point of detonation regardless of bomb size.

To create craters (used to destroy supply roads, runways, or deny terrain to the enemy), planners can outfit GP bombs with delay fuzes. This arrangement allows the bomb to penetrate the surface before detonation and results in a large crater. Delay fuzes will also allow a GP bomb to penetrate building roofs before detonation resulting in greater destructive effect to the building.

General Characteristics:

Range: Varies depending on release altitude.

Length: 10 feet 9 inches
Diameter: 1 foot 6 inches
Weight: About 2,000 pounds
Warhead: The BLU-111 contains 945 pounds of PBXN-109 explosive. A variety of mechanical (impact) nose and tail fuzes and electrical fuzes (used to explode the bomb in the air above the target) can denote the bomb.
Guidance System: Ballistic
Control: Fin assemblies cause the bomb to fall in a smooth, definite curve toward the target, instead of tumbling through the air. The BLU-112 uses conical, low-drag fins for medium and high-altitude delivery. Retarded fins allow a delivery aircraft to drop the bomb at high-speed and low altitude and escape the blast and fragmentation of the bomb denotation. The BLU-112 uses the BSU-50 high drag tail assembly. The BSU-50 deploys an air-inflated retarder (basically a bag filled with air) to slow the bomb's descent. Retarded fins have the capability to be used in both a retarded and non-retarded mode.
Propulsion: None
Unit Cost: $5,384
Date Deployed: 1985
Delivery Aircraft: A-10, B-1B, B-52H, F-14, F-15, F-16, F/A-18, and the F-117.
Contractor: Inventory



Aviation ordnancemen install a Joint Direct Attack Munitions Kit to a 2,000 pound BLU-112 bomb. *Photo courtesy of the U.S. Navy.*

Military Nomenclature: BLU-113

Name: 5,000 lb. Penetrator

Description: A 4,400-pound bomb made from surplus 8-inch artillery tubes, the BLU-113 contains 630 pounds of Tritonal high-explosive. Designed to penetrate hardened targets, it employs a tail fuze to detonate the bomb after it has knifed its way deep into the heart of its target. Engineers have mated the massive bomb with a Paveway III laser guidance unit and Paveway II fins to produce the GBU-28. The nose-mounted Paveway III laser guidance unit includes canards (small wings) that react to commands from the onboard guidance system to steer the weapon to a target illuminated by an external laser source. The tail-mounted Paveway II flight stability fins provide additional lift. The bomb does not ride down the laser beam as is often thought. Instead, the seeker uses the laser spot reflecting off the target as a reference point to stay on course (the guidance unit keeps the laser spot in the center of its field of view).

The basic process of a laser-guided bomb engagement is as follows: the pilot releases a laser-guided bomb at an altitude and angle that will give it sufficient speed and range to reach the target; the delivery aircraft, a second aircraft, an unmanned aerial vehicle, or a person on the ground projects a laser onto the target (known as laser "designation"); the pilot activates the seeker head in the guidance unit of the laser-guided bomb; the seeker head finds the laser spot and moves the weapon's canards (small wings mounted on the nose) to steer the bomb to the target.

The GBU-28 can penetrate more than 20 feet of concrete or more than 100 feet of earth earning it the title of the "bunker buster."

Employment Considerations: Lasers cannot penetrate clouds. Highly accurate in fair weather, laser guided bombs don't work well when bad weather obscures the target.

To achieve maximum accuracy, aircraft crews drop laser-guided bombs at altitudes from 15,000 to 23,000 feet (known as the mid-altitude range). A mid-altitude range release gives the crew maximum opportunity to identify and "designate" the target with the targeting laser. The mid-altitude range also gives the weapon's steering fins ample time to adjust the bomb's flight and strike the target.

If penetration warheads strike the target at an angle they tend to

bounce off the target, a characteristic often referred to as the J-hook effect.

The U.S. military measures bomb accuracy using a calculation known as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The GBU-28 has a CEP of 30 feet.

General Characteristics:

Range: 6 miles when mated with a guidance kit and a set of aerodynamic control surfaces to create the GBU-28, a laser-guided bomb.
Length: 12 feet 9 inches
Diameter: 1 foot 2.5 inches
Weight: 4,400 pounds
Warhead: A 4,400-pound bomb made from surplus 8-inch artillery tubes, the BLU-113 contains 630 pounds of Tritonal high explosive. Designed to penetrate hardened targets, it employs a tail fuze that detonates the bomb after it has knifed its way deep into the heart of the target. The fuze is attached to the tail to prevent it from being crushed when the bomb strikes the target. The bomb can penetrate 20 feet of concrete or more than 100 feet of earth.
Guidance System: The BLU-113 is mated with Paveway III guidance and control and Paveway II fins to create the laser-guided GBU-28. The Paveway III features a front-end guidance unit that acquires the reflected laser energy from a target illuminated by an external laser source. The Paveway III seeker has a wider field of view and greater sensitivity than its predecessors. While the Paveway II guidance unit can only fully deflect its canards (known as bang-bang guidance), the Paveway III guidance unit can deflect its canards incrementally to bring the laser spot back to the center of the seeker's field of view (known as proportional guidance). Proportional guidance improves performance of the weapon during flight and gives the pilot a larger delivery envelope. Earlier Paveway laser-guided bombs required strict release parameters to solve speed and wind drift problems. The Paveway III can shape the terminal trajectory of the GBU-28 to create the optimum impact angle against the target - it will strike a target such as an underground command and control facility at a vertical angle but fly a horizontal approach to strike a bridge support.
Control: The BLU-113 is always used as a warhead and mated with a guidance kit and a set of aerodynamic control surfaces to form the GBU-28, a laser-guided bomb. The GBU-28 employs an airfoil group which includes

canards (small wings mounted on the nose) and tail-mounted flight stability fins. The canards react to commands from the onboard guidance system to steer the weapon to the target illuminated by an external laser source.
Propulsion: None
Unit Cost: $55,566
Date Deployed: 1991
Delivery Aircraft: F-15E.
Contractor: Lockheed Martin and National Forge

Aircrew inspect a GBU-28, which uses the BLU-113 as its warhead. The kneeling airman has his hands on the BLU-113. *Photo courtesy of the US Air Force.*

Military Nomenclature: BLU-116

Name: Advanced Unitary Penetrator (AUP)

Description: A 2,000-pound air-to-surface warhead designed to have twice the penetration capability of the BLU-109. An aluminum shroud gives the steel-cased warhead the same flight characteristics and weapon interface as the BLU-109, which allows the use of the BLU-116 on precision guided weapons that typically use the BLU-109. The bomb uses the Hard Target

Smart Fuze, which detonates the warhead when it reaches a specific depth inside the target. Planners use the BLU-116 to destroy deeply buried or fortified targets, particularly those containing weapons of mass destruction.

Employment Considerations: If penetration warheads strike the target at an angle they tend to bounce off the target, a characteristic often referred to as the J-hook effect.

General Characteristics:

Range: None. The BLU-116 is always used as a warhead.
Length: 8 feet 2.5 inches
Diameter: 1 foot 2.5 inches
Weight: 1,927 pounds
Warhead: The BLU-116 has a narrow diameter case made of a nickel-cobalt steel alloy designed to penetrate hardened structures. Since the warhead replaces the BLU-109, engineers encased it in an aluminum shroud that duplicates the dimensions, mass, and aerodynamics of the BLU-109 (this allows weapon systems designed to carry the BLU-109 to use the BLU-116). The shroud strips away when the warhead strikes the target. The BLU-116 contains 240 pounds of PBXN explosive and uses the Hard Target Smart Fuze (HTSF), which allows penetrating warheads to detonate at a desired depth inside the target. The BLU-116 has twice the penetration capability of the BLU-109.
Guidance System: The BLU-116 has no guidance capability. It does serve as the warhead for precision guided munitions such as the GBU-15, GBU-24, GBU-27, and the AGM-130. See those weapon systems for their guidance capabilities.
Control: The BLU-116 has no aerodynamic flight control surfaces. It does serve as the warhead for precision guided munitions such as the GBU-15, GBU-24, GBU-27, and the AGM-130. See those weapon systems for their aerodynamic flight control surfaces.
Propulsion: The BLU-116 has no propulsion. It does serve as the warhead for the rocket powered AGM-130.
Unit Cost: $44,000
Date Deployed: 1999
Delivery Aircraft: The BLU-116 serves as the warhead for precision guided munitions, primarily the GBU-15, GBU-24, GBU-27, and the AGM-130. See those weapon systems for their delivery aircraft.
Contractor: National Forge and Alliant Techsystems

The BLU-116 Advanced Unitary Penetrator (AUP) serves as the warhead for the GBU-24 shown here. *Photo courtesy of the Department of Defense.*

Military Nomenclature: BLU-118

Name: Thermobaric Warhead

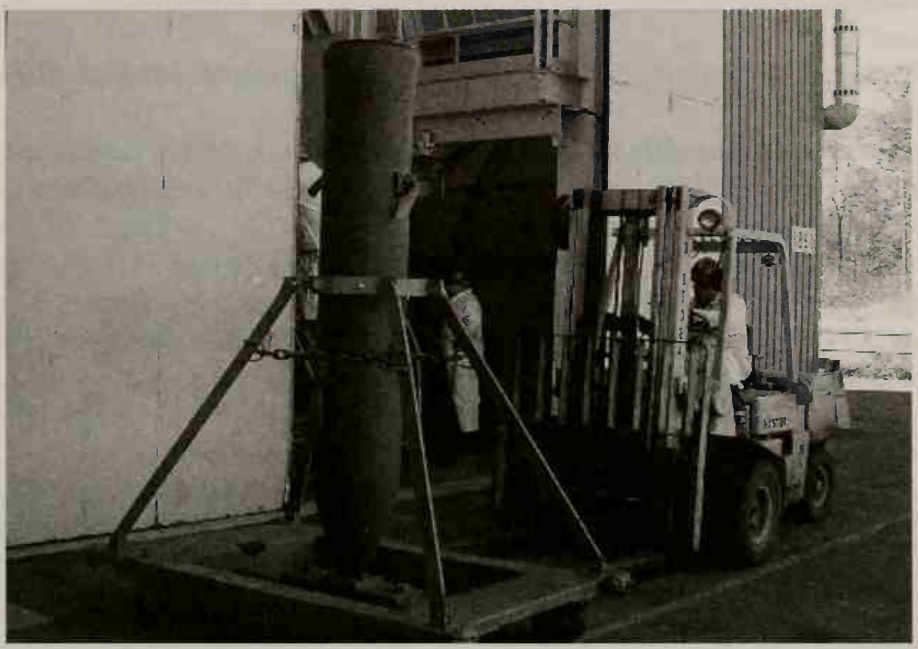
Description: The BLU-118 destroys caves, tunnels, and underground bunkers. The bomb uses the same penetrating warhead as the BLU-109. Engineers simply replaced the high explosive used in the BLU-109 with a thermobaric explosive (PBXIH-135). Thermobaric explosives generate greater blast pressures than traditional explosives and in a confined space such as a tunnel the overpressure and heat wave of the thermobaric explosion will travel farther than that of a high explosive.

Employment Considerations: To defeat caves and tunnels, aircraft employ the BLU-118 in a vertical delivery or a skip bomb attack. Vertical delivery attacks include exploding the bomb just outside the mouth of the cave or penetrating the overburden near the entrance of the cave and exploding the bomb just inside the cave entrance. Two skip bomb methods have proven successful. The first involves skipping a bomb equipped with a short time-delay fuze into the entrance of a tunnel. The second method uses a long time-delay

fuze, which allows the bomb to travel well inside the tunnel before detonation.

General Characteristics:

Range: None. The BLU-118 is always used as a warhead.
Length: 8 feet 2.5 inches
Diameter: 1 foot 2.5 inches
Weight: 1,975 pounds
Warhead: The BLU-118 uses the same penetrating warhead as the BLU-109. Engineers simply replaced the high explosive used in the BLU-109 with a thermobaric explosive (PBXIH-135). The explosive PBXIH-135 consists of a common military explosive called HMX, polyurethane rubber, and aluminum powder. Thermobaric explosives generate greater blast pressures than traditional explosives and in a confined space such as a tunnel the overpressure and heat wave of the thermobaric explosion will travel farther than that of a traditional high explosive. The bomb uses a tail-mounted, time-delay fuze to detonate the warhead after penetration.
Guidance System: The BLU-118 has no guidance capability. It does serve as the warhead for precision-guided munitions such as the GBU-10, GBU-15, GBU-24, GBU-31 and the AGM-130. See those weapon systems for their guidance capabilities.
Control: The BLU-118 has no aerodynamic flight control surfaces. It does serve as the warhead for precision-guided munitions such as the GBU-10, GBU-15, GBU-24, GBU-31 and the AGM-130. See those weapon systems for their aerodynamic flight control surfaces.
Propulsion: The BLU-118 has no propulsion. It does serve as the warhead for the rocket powered AGM-130.
Unit Cost: Not reported.
Date Deployed: 2001
Delivery Aircraft: The BLU-118 serves as a warhead for precision-guided munitions, primarily the GBU-10, GBU-15, GBU-24, GBU-31, and the AGM-130. See those weapon systems for the delivery aircraft used to delivery the munitions.
Contractor: Defense Threat Reduction Agency



Workers at the Naval Surface Warfare Center prepare a BLU-118 thermobaric bomb for shipment. *Photograph courtesy of the U.S. Navy.*

Military Nomenclature: LBU-30

Name: Leaflet Bomb

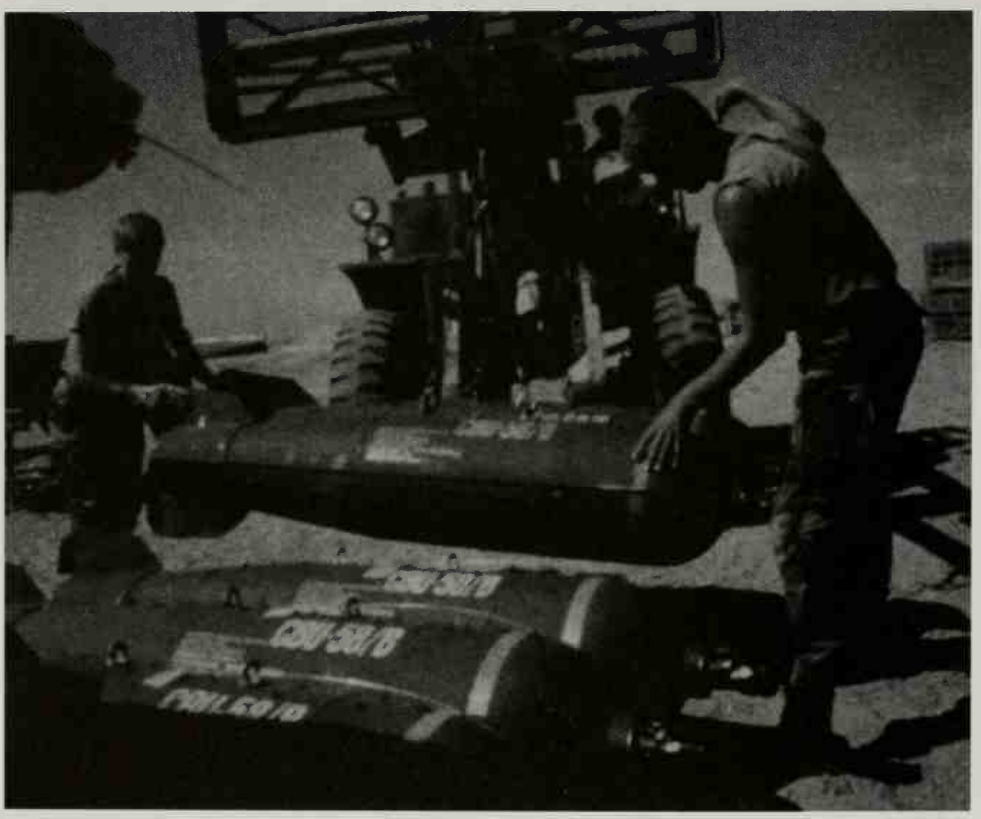
Description: A SUU-30 cluster munition dispenser modified to dispense propaganda leaflets. After release from the delivery aircraft, a proximity fuze (a fuze that fires at a preset altitude) pops open the canister causing it to split like a clam shell and scatter the leaflets into the wind.

Employment Considerations: High winds can cause leaflets to miss the target area.

General Characteristics:

Range: Varies depending on release altitude.
Length: 7 feet 9 inches
Diameter: 1 foot 4 inches

Weight: Varies depending on the number of leaflets carried and the type of paper used.
Warhead: A proximity fuze (a fuze that fires at a preset altitude) splits open the dispenser.
Guidance System: Ballistic
Control: The SUU-30 uses fixed tailfins to stabilize its flight and impart a spin that helps scatter the leaflets.
Propulsion: None
Unit Cost: Minimal (obsolete cluster munitions already in the inventory provide the SUU-30 dispensers used to construct LBU-30 leaflet bombs).
Date Deployed: 2000
Delivery Aircraft: A-10, B-52H, F-15, F-16, and the F-117.
Contractor: US Air Force Information Warfare Battlelab



Air Force troops stack CBU-58 cluster bombs during Operation Desert Storm. The LBU-30 uses the same dispenser - the SUU-30 - as the CBU-52, CBU-58, and the CBU-71. *Photo courtesy of the U.S. Air Force.*

Military Nomenclature: M-117

Name: 750 lb. GP Bomb

Description: An unguided, 750-pound, general-purpose bomb employed in three configurations. The basic M-117 uses low-drag tail fins for medium and high-altitude delivery. To attack targets at high-speed and low level, planners use the M-117R and M-117 AIR variants. After release, the M-117R deploys four large drag plates that slow the bomb's descent and allow the delivery aircraft to escape the blast zone before the bomb impacts the target. The M-117 AIR uses an air-inflated retarder (basically a bag filled with air) to slow the bomb's descent.

Employment Considerations: Compact in design, the M-117 allows the B-52 to carry more bomb tonnage. Used extensively during the Vietnam War and Operation Desert Storm, M-117 inventories have been seriously depleted.

The optimum release altitude for non-guided bombs is 5,000 feet, which places the delivery aircraft within easy reach of ground fire. To safeguard aircraft and flight crews, American air commanders restrict delivery aircraft to bombing altitudes above 15,000 feet. Since this tactic affects the accuracy of non-guided bombs, planners only use these weapons in areas where there is little chance of civilian casualties or collateral damage.

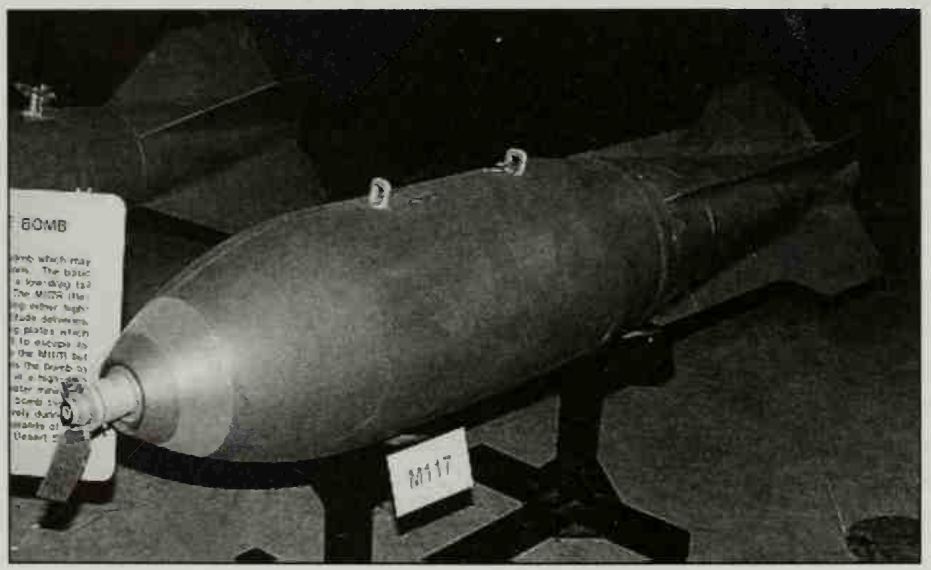
General-purpose bombs destroy targets through blast and fragmentation. When a bomb explodes, the energy released compresses the surrounding air. These tremendous overpressures can knock down buildings, destroy machinery, and kill personnel by damaging internal organs. The blast effect will only kill humans for a short distance from the explosion. For example, a 2,000-pound GP bomb will kill a human through blast effect up to 110 feet from the point of detonation. An exploding general-purpose bomb will also create many bomb fragments. These fragments achieve velocities ranging from 5,000 to 9,000 feet per second and will kill personnel and destroy equipment at much greater ranges. Effective against personnel, vehicles, and aircraft, these fragments can kill up to 3,000 feet from the point of detonation regardless of bomb size.

To create craters (used to destroy supply roads, runways, or deny terrain to the enemy), planners can outfit GP bombs with delay fuzes. This arrangement allows the bomb to penetrate the surface before detonation and results in a large crater. Delay fuzes will also allow a GP bomb to

penetrate building roofs before detonation resulting in greater destructive effect to the building.

General Characteristics:

Range: Varies depending on release altitude.
Length: 4 feet 3.5 inches
Diameter: 1 foot 10 inches (with fins installed)
Weight: 737 lbs.
Warhead: A traditional blast and fragmentation bomb, the M-117 consists of a conical-shaped, steel bomb case containing 386 pounds of Tritonal or 383 pounds of Minol II explosive detonated by a variety of mechanical or electrical fuzes.
Guidance System: Ballistic
Propulsion: None
Unit Cost: about $1,000
Date Deployed: Korean War
Delivery Aircraft: A-10, F-15E, and the B-52H.
Contractor: Inventory



An M-117 750- pound general-purpose bomb displayed at the USAF Museum.
Photo courtesy of the U.S. Air Force Museum.

Military Nomenclature: M-129

Name: 200 lb. Leaflet Bomb

Description: The M-129 bomb allows high-flying aircraft to drop propaganda leaflets on a target area. The bomb consists of two longitudinal sections held together by four latches on each side. At the desired altitude, an airburst fuze in the nose of the bomb body sets off detonation cord placed in the seam between the two longitudinal sections. The detonation cord separates the sections, detaches the fins, and scatters the leaflets into the wind. The M-129 can hold between 60,000 to 80,000 leaflets.

Employment Considerations: High winds can cause leaflets to miss the target area.

Aging and heavy use have depleted the M-129 inventory.

General Characteristics:

Range: Varies depending on release altitude.
Length: 7 feet 6 inches
Diameter: 1 foot 10 inches (with fins installed)
Weight: About 200 pounds when loaded with leaflets. The weight varies according to the paper used.
Warhead: The bomb consists of two longitudinal sections held together by four latches on each side. At the desired altitude, an airburst fuze in the nose of the bomb body sets off detonation cord placed in the seam between the two longitudinal sections. The detonation cord separates the sections, detaches the fins, and scatters the leaflets into the wind.
Guidance System: Ballistic
Control: Fin assemblies cause the bomb to fall in a smooth, definite curve toward the target instead of tumbling through the air. The M-129 uses low-drag fins.
Propulsion: None
Unit Cost: Inventory
Date Deployed: World War II
Delivery Aircraft: A-10, B-52H, F-15E, F-16 and F/A-18.
Contractor: Inventory

Troops loading leaflets into M-129 leaflet bombs during Operation Iraqi Freedom. Photograph courtesy of the USAF.

Military Nomenclature: MK-82

Name: 500 lb. General Purpose Bomb

Description: Developed in the 1950s, the MK-80 series of general-purpose bombs have an aerodynamic, cylindrical shape that reduces drag, an important factor when high-speed aircraft carry bombs hung on their wings. Planners use the MK-82 against targets vulnerable to blast and explosive effects. It is not designed to penetrate hard targets. Typical targets include troops, artillery emplacements, truck parks, and radars.

Employment Considerations: The optimum release altitude for unguided bombs is 5,000 feet, which places the delivery aircraft within easy reach of ground fire. To safeguard aircraft and flight crews, American air commanders restrict delivery aircraft to bombing altitudes above 15,000 feet. Since this tactic affects the accuracy of unguided bombs, planners only use these weapons in areas where there is little chance of civilian casualties or collateral damage.

General-purpose bombs destroy targets through blast and fragmentation. When a bomb explodes, the energy released compresses the surrounding air. These tremendous overpressures can knock down buildings, destroy machinery, and kill personnel by damaging internal organs. The blast effect will only kill humans for a short distance from the explosion. For example, a

2,000-pound GP bomb will kill a human through blast effect up to 110 feet from the point of detonation. An exploding general-purpose bomb will also create many bomb fragments. These fragments achieve velocities ranging from 5,000 to 9,000 feet per second and will kill personnel and destroy equipment at much greater ranges. Effective against personnel, vehicles, and aircraft these fragments can kill up to 3,000 feet from the point of detonation regardless of bomb size.

To create craters (used to destroy supply roads, runways, or deny terrain to the enemy), planners can outfit GP bombs with delay fuzes. This arrangement allows the bomb to penetrate the surface before detonation and results in a large crater. Delay fuzes will also allow a GP bomb to penetrate building roofs before detonation resulting in greater destructive effect to the building.

General Characteristics:

Range: Varies depending on release altitude.
Length: 5 feet 6.2 inches
Diameter: 10.75 inches
Weight: About 500 pounds (the weight varies depending on the stabilizer used).
Warhead: The MK-82 contains 192 pounds of Tritonal, Minol II, or H-6 explosive. A variety of mechanical (impact) nose and tail fuzes and electrical fuzes (used to explode the bomb in the air above the target) can denote the bomb.
Guidance System: Ballistic
Control: Fin assemblies cause the bomb to fall in a smooth curve toward the target instead of tumbling through the air. The MK-82 uses conical, low-drag fins for medium and high-altitude delivery. Retarded fins allow a delivery aircraft to drop the bomb at high-speed and low altitude and escape the blast and fragmentation of the bomb denotation. The MK-82 uses two types of retarded fins: the MK-15 Snakeye, which deploys four large drag plates that slow the bomb's descent, and the BSU-49, which deploys an air-inflated retarder (basically a bag filled with air) to slow the bomb's descent. Retarded fins have the capability to be used in both a retarded and non-retarded mode.
Propulsion: None
Unit Cost: $2,082.50.

Date Deployed: 1950
Delivery Aircraft: A-10 B-1B, B-52H F-14, F-15, F-16, F/A-18, and the F-117.
Contractor: Inventory

An airman guides an MK-82 bomb into the weapons bay of a B-1B bomber. *Photo courtesy of the Department of Defense.*

Military Nomenclature: MK-83

Name: 1,000 lb. General Purpose Bomb

Description: Developed in the 1950s, the MK-80 series of general-purpose bombs have an aerodynamic, cylindrical shape that reduces drag, an important factor when high-speed aircraft carry bombs hung on their wings. Planners use the MK-83 against targets vulnerable to blast and explosive effects. It is not designed to penetrate hard targets. Typical targets include troops, artillery emplacements, truck parks, and radars. their wings. Planners use the MK-82 against targets vulnerable to blast and explosive effects. It is not designed to penetrate hard targets. Typical targets include troops, artillery emplacements, truck parks, and radars.

Employment Considerations: The optimum release altitude for unguided bombs is 5,000 feet, which places the delivery aircraft within easy reach of ground fire. To safeguard aircraft and flight crews, American air commanders restrict delivery aircraft to bombing altitudes above 15,000 feet. Since this tac-

tic affects the accuracy of unguided bombs, planners only use these weapons in areas where there is little chance of civilian casualties or collateral damage.

General-purpose bombs destroy targets through blast and fragmentation. When a bomb explodes, the energy released compresses the surrounding air. These tremendous overpressures can knock down buildings, destroy machinery, and kill personnel by damaging internal organs. The blast effect will only kill humans for a short distance from the explosion. For example, a 2,000-pound GP bomb will kill a human through blast effect up to 110 feet from the point of detonation. An exploding general-purpose bomb will also create many bomb fragments. These fragments achieve velocities ranging from 5,000 to 9,000 feet per second and will kill personnel and destroy equipment at much greater ranges. Effective against personnel, vehicles, and aircraft, these fragments can kill up to 3,000 feet from the point of detonation regardless of bomb size.

To create craters (used to destroy supply roads, runways, or deny terrain to the enemy), planners can outfit GP bombs with delay fuzes. This arrangement allows the bomb to penetrate the surface before detonation and results in a large crater. Delay fuzes will also allow a GP bomb to penetrate building roofs before detonation resulting in greater destructive effect to the building.

General Characteristics:

Range: Varies depending on release altitude.
Length: 9 feet 7 inches
Diameter: 1 foot 2 inches
Weight: 1,000 pounds
Warhead: The MK-83 contains 445 pounds of H-6, PBXN-109, or Tritonal explosive. A variety of mechanical (impact) nose and tail fuzes and electrical fuzes (used to explode the bomb in the air above the target) can denote the bomb.
Guidance System: Ballistic
Control: Fin assemblies cause the bomb to fall in a smooth, definite curve toward the target, instead of tumbling through the air. The MK-83 uses conical, low-drag fins for medium and high-altitude delivery. Retarded fins allow a delivery aircraft to drop the bomb at high-speed and low altitude and escape the blast and fragmentation of the bomb denotation. The MK-83 uses the

BSU-85 high drag tail assembly. The BSU-85 deploys an air-inflated retarder (basically a bag filled with air) to slow the bomb's descent. Retarded fins have the capability to be used in both a retarded and non-retarded mode.
Propulsion: None
Unit Cost: $3,128.83
Date Deployed: 1950s
Delivery Aircraft: A-10 F-14, F-15, F-16, and the F/A-18.
Contractor: Inventory

Ordnancemen transport MK-83 bombs cross the flight deck of the USS George Washington.
Photo courtesy of the Department of Defense.

Military Nomenclature: MK-84

Name: 2,000 lb. General Purpose Bomb

Description: Developed in the 1950s, the MK-80 series of general-purpose bombs have an aerodynamic, cylindrical shape that reduces drag, an important factor when high-speed aircraft carry bombs hung on their wings. Planners use the MK-84 against targets vulnerable to blast and explosive effects. It is not designed to penetrate hard targets. Typical targets include troops, artillery emplacements, truck parks, and radars.

Employment Considerations: The optimum release altitude for unguided

bombs is 5,000 feet, which places the delivery aircraft within easy reach of ground fire. To safeguard aircraft and flight crews, American air commanders restrict delivery aircraft to bombing altitudes above 15,000 feet. Since this tactic affects the accuracy of unguided bombs, planners only use these weapons in areas where there is little chance of civilian casualties or collateral damage.

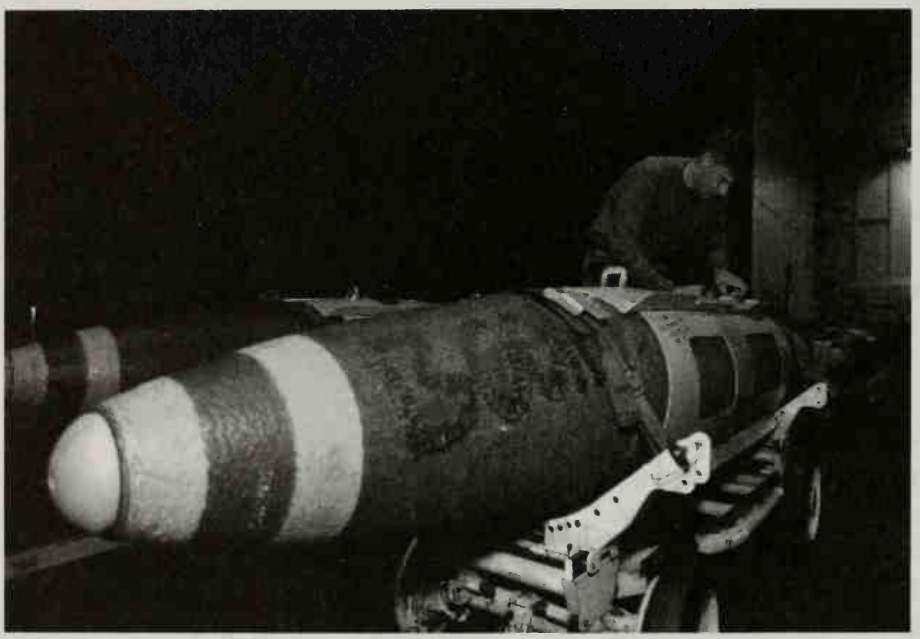
General-purpose bombs destroy targets through blast and fragmentation. When a bomb explodes, the energy released compresses the surrounding air. These tremendous overpressures can knock down buildings, destroy machinery, and kill personnel by damaging internal organs. The blast effect will only kill humans for a short distance from the explosion. For example, a 2,000-pound GP bomb will kill a human through blast effect up to 110 feet from the point of detonation. An exploding general-purpose bomb will also create many bomb fragments. These fragments achieve velocities ranging from 5,000 to 9,000 feet per second and will kill personnel and destroy equipment at much greater ranges. Effective against personnel, vehicles, and aircraft, these fragments can kill up to 3,000 feet from the point of detonation regardless of bomb size.

To create craters (used to destroy supply roads, runways, or deny terrain to the enemy), planners can outfit GP bombs with delay fuzes. This arrangement allows the bomb to penetrate the surface before detonation and results in a large crater. Delay fuzes will also allow a GP bomb to penetrate building roofs before detonation resulting in greater destructive effect to the building.

General Characteristics:
Range: Varies depending on release altitude.
Length: 10 feet 9 inches
Diameter: 1 foot 6 inches
Weight: About 2,000 pounds
Warhead: The MK-84 contains 945 pounds of H-6 or Tritonal explosive. A variety of mechanical (impact) nose and tail fuzes and electrical fuzes (used to explode the bomb in the air above the target) can denote the bomb.
Guidance System: Ballistic
Control: Fin assemblies cause the bomb to fall in a smooth, definite curve toward the target, instead of tumbling through the air. The MK-84 uses conical, low-drag fins for medium and high-altitude delivery. Retarded fins allow a delivery aircraft to drop the bomb at high-speed and low altitude and escape

the blast and fragmentation of the bomb denotation. The MK-84 uses the BSU-50 high drag tail assembly. The BSU-50 deploys an air-inflated retarder (basically a bag filled with air) to slow the bomb's descent. Retarded fins have the capability to be used in both a retarded and non-retarded mode.

Propulsion: None
Unit Cost: $5,384.40
Date Deployed: 1950s
Delivery Aircraft: A-10 B-1B, B-52H, F-14, F-15, F-16, F/A-18, and the F-117.
Contractor: Inventory



An aviation ordnanceman installs a JDAM kit on a 2,000-pound MK-84 bomb during Operation Enduring Freedom. *Photo courtesy of the U.S. Navy.*

Chapter 4: Guided Munitions

MILITARY NOMENCLATURE: GBU-10

NAME: 2000 LB. PAVEWAY II LASER-GUIDED BOMB

Description: A member of the Paveway series of laser-guided bombs, the GBU-10 consists of a MK-84 2,000-pound general-purpose bomb or BLU-109 penetration warhead mated with a Paveway II laser guidance kit. The kit includes a nose-mounted laser guidance and control group and an airfoil group, which includes canards (small wings mounted on the nose) and tail-mounted flight stability fins. The canards react to commands from the guidance on board system to steer the weapon to a target illuminated by an external laser source. The bomb does not ride down the laser beam as is often thought. Instead, the seeker uses the laser spot reflecting off the target as a reference point to stay on course (the guidance unit keeps the laser spot in the center of its field of view).

The basic process of a laser-guided bomb engagement is as follows: the delivery aircraft, a second aircraft, an unmanned aerial vehicle, or a person on the ground projects a laser onto the target (known as laser "designation"); the pilot activates the seeker head in the guidance unit of the laser-guided bomb; the pilot releases the laser-guided bomb at an altitude and angle that will give it sufficient speed and range to reach the target; the guidance unit keeps the laser spot centered in the seeker's field of view by moving the weapon's canards to steer the bomb to the target (the laser spot).

Planners use the MK-84 version of the GBU-10 against both mobile and fixed soft targets and the BLU-109 version against fixed hard targets.

Employment Considerations: Lasers cannot penetrate clouds. Highly accurate in fair weather, laser guided bombs don't work well when bad weather obscures the target.

To achieve maximum accuracy, aircraft crews drop laser-guided bombs

at altitudes from 15,000 to 23,000 feet (known as the mid-altitude range). A mid-altitude range release gives the crew maximum opportunity to identify and "designate" the target with the targeting laser. The mid-altitude range also gives the weapon's steering fins ample time to adjust the bomb's flight and strike the target. If necessary, however, the crew can drop laser-guided bombs at low level.

The U.S. military measures bomb accuracy using a calculation known as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The GBU-10 has a CEP of 30 feet.

General Characteristics:

Range: 5 miles. Actual range depends on release altitude.
Length: 14 feet
Diameter: 1 foot 6 inches
Weight: 2,081 pounds
Warhead: The MK-84 contains 945 pounds of H-6 or Tritonal explosive. The BLU-109 has a one-inch thick case made of high-strength steel designed to penetrate hardened structures. The bomb contains 550 pounds of Tritional explosive and uses a tail-mounted, time-delay fuze to detonate the warhead after penetration.
Guidance System: To guide itself to the target, the GBU-10 uses the Paveway II guidance system. The Paveway features a front-end guidance unit that acquires the reflected laser energy from a target illuminated by an external laser source. The laser designator (the external laser source) and the laser seeker in the Paveway system use pulse coding to ensure the GBU-10 tracks the correct target. The coding system uses the numbers one through eight set in three to four digit codes. The designator and the seeker must share the same code to work in harmony and guide the bomb. This system allows simultaneous attacks against multiple targets with laser guided weapons and prevents the enemy from using another laser designator to lure the bomb off target. The laser receiver in the guidance unit derives the target location by using an array of photodiodes to sense reflecting laser energy. To stay on target, the sensor keeps the laser spot in the center of its field of view. When the laser spot moves off center, the guidance computer fully deflects the canards to keep

the laser spot in the center of the sensor's field of view. This combination of an "on-off" seeker and hard-over movement of controls is called "bang-bang" guidance. It works well at high speed, but accuracy decreases as the weapon's speed decreases.

Control: The Paveway II deploys its tail-mounted wings, which provide additional lift and aerodynamic stability, after release from the aircraft. The canards (small wings mounted on the nose) react to commands from the onboard guidance system to steer the weapon to a target illuminated by an external laser source.

Propulsion: None

Cost: $25,294 (MK-84 version)
$35,657 (BLU-109 version)

Date Deployed: 1976

Delivery Aircraft: A-10, B-52H, F-14, F-15E, F-16, F/A-18, and the F-117.

Contractor: Raytheon

A GBU-10 captured by the camera just before it strikes its target. *Photo courtesy of Lockheed Martin.*

Military Nomenclature: GBU-12

Name: 500 lb. Paveway II Laser-Guided Bomb

Description: A member of the Paveway series of laser-guided bombs, the GBU-12 is a MK-82 500-pound general-purpose bomb mated with a Paveway II laser guidance kit. The kit includes a nose mounted laser guidance and control group and an airfoil group, which includes canards (small wings mounted on the nose) and tail-mounted flight stability fins. The canards react to commands from the onboard guidance system to steer the weapon to a target illuminated by an external laser source. The bomb does not ride down the laser beam as is often thought. Instead, the seeker uses the laser spot reflecting off the target as a reference point to stay on course (the guidance unit keeps the laser spot in the center of its field of view).

The basic process of a laser-guided bomb engagement is as follows: the delivery aircraft, a second aircraft, an unmanned aerial vehicle, or a person on the ground projects a laser onto the target (known as laser "designation"); the pilot activates the seeker head in the guidance unit of the laser-guided bomb; the pilot releases the laser-guided bomb at an altitude and angle that will give it sufficient speed and range to reach the target; the guidance unit keeps the laser spot centered in the seeker's field of view by moving the weapon's canards to steer the bomb to the target (the laser spot).

Planners use the GBU-12 against both mobile and fixed soft targets.

Employment Considerations: Lasers cannot penetrate clouds. Highly accurate in fair weather, laser guided bombs don't work well when bad weather obscures the target.

To achieve maximum accuracy, aircraft crews drop laser-guided bombs at altitudes from 15,000 to 23,000 feet (known as the mid-altitude range). A mid-altitude range release gives the crew maximum opportunity to identify and "designate" the target with the targeting laser. The mid-altitude range also gives the weapon's steering fins ample time to adjust the bomb's flight and strike the target. If necessary, however, the crew can drop laser-guided bombs at low level.

The U.S. military measures bomb accuracy using a calculation known as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The

GBU-16 has a CEP of 30 feet.

General Characteristics:

Range: 5 miles. Actual range depends on release altitude.
Length: 10 feet 11 inches
Diameter: About 11 inches (warhead)
18 inches (airfoil groups)
Weight: 611 pounds
Warhead: The GBU-12 uses the MK-82 (500-pound GP bomb) for its warhead. The MK-82 contains 192 pounds of Tritonal, Minol II, or H-6 explosive.
Guidance System: To guide itself to the target, the GBU-12 uses a Paveway II guidance system. The Paveway features a front-end guidance unit that acquires the reflected laser energy from a target illuminated by an external laser source. The laser designator (the external laser source) and the laser seeker in the Paveway system use pulse coding to ensure the GBU-12 tracks the correct target. The coding system uses the numbers one through eight set in three to four digit codes. The designator and the seeker must share the same code to work in harmony and guide the bomb. This system allows simultaneous attacks against multiple targets with laser guided weapons and prevents the enemy from using another laser designator to lure the bomb off target. The laser receiver in the guidance unit derives the target location by using an array of photodiodes to sense reflecting laser energy. To stay on target, the sensor keeps the laser spot in the center, of its field of view. When the laser spot moves off center the guidance computer fully deflects the canards to keep the laser spot in the center of the sensor's field of view. This combination of an "on-off" seeker and hard-over movement of controls is called "bang-bang" guidance. It works well at high speed, but accuracy decreases as the weapon's speed decreases.
Control: The Paveway II deploys its tail-mounted wings, which provide additional lift and aerodynamic stability, after release from the aircraft. The canards (small wings mounted on the nose) react to commands from the onboard guidance system to steer the weapon to a target illuminated by an external laser source.
Propulsion: None
Unit Cost: $20,189

Date Deployed: 1976
Delivery Aircraft: A-10, B-52H, F-14, F-15E, F-16, F/A-18, and the F-117.
Contractor: Raytheon

The GBU-12 delivers a 500-pound warhead. *Photo courtesy of the U.S. Air Force Museum.*

Military Nomenclature: GBU-15

Name: Guided Standoff Weapon

Description: A glide bomb, the GBU-15 consists of a 2,000-pound bomb mated with a TV or imaging infrared seeker and a set of aerodynamic control surfaces. Wings give the GBU-15 greater range than laser guided bombs and the use of TV or imaging infrared seekers allows the delivery aircraft to launch the weapon before locking onto the target. The pilot or weapon systems officer (WSO) can locate the target with the seeker (a video will appear on a dis-

play in the cockpit) after the drop. Laser guided bombs require that the crew get close enough to the target to identify and designate it with a targeting laser. The GBU-15 allows the launch aircraft to remain at a safe distance from the target.

The EGBU-15 (Enhanced GBU-15) incorporates GPS/INS guidance to obtain extreme accuracy in adverse weather conditions.

Planners use the GBU-15 against high-value, heavily defended enemy targets.

Employment Considerations: The standoff capability of the GBU-15 increases the survivability of the launch aircraft in high threat environments.

The GBU-15 can guide itself to the target or the WSO can guide it through a data link system while observing a video transmitted by the weapon. The latter allows the WSO to select an aimpoint on the target that will produce the most damage.

General Characteristics:

Speed: Classified
Range: 13 miles. Actual range depends on release altitude.
Length: Varies between 12 feet 8 inches and 13 feet 1.5 inches depending on warhead and airfoil group used.
Diameter: Varies between 18 and 25 inches depending on warhead and airfoil group used.
Weight: Varies between 2,244 and 3,655 pounds depending on warhead and airfoil group used.
Wing Span: 4 feet 11 inches
Warhead: The GBU-15 uses either the MK-84, a 2,000-pound general purpose bomb, or the BLU-109, a 2,000-pound bomb designed to penetrate hard targets, as its warhead.
Guidance System: The launch aircraft's WSO can lock onto the target before missile launch and allow the GBU-15 to guide itself to the target, or he can manually steer the missile. Normally, the pilot will fly the aircraft to a prebriefed launch position and the WSO will launch the glide bomb when he receives seeker signals. After launch, the weapon travels to the target using its inertial navigation system assisted by a global positioning satellite system. The

WSO can control the missile at any time through a two-way communications system (the AN/AXQ-14 Data Link System). Inside the cockpit, the WSO has a display that shows him the image acquired by the television or infrared imaging sensor in the bomb's nose. When the weapon transitions into the terminal phase of the flight (15 seconds before impact), the WSO locks the seeker onto the target or takes control of the missile and manually guides it to the impact point. The AGM-130 can also be launched from one aircraft and guided by another.

The EGBU-15 incorporates GPS/INS guidance to obtain extreme accuracy in adverse weather conditions.

Control: The GBU-15 uses four small wings in an X-like arrangement mounted on the front and rear sections to obtain flight stability. The wings on the rear section have trailing edge flap control surfaces used for flight maneuvering.

Propulsion: None

Unit Cost: $234,794 (TV guidance with MK-84 warhead)
$231,856 (IR guidance with MK-84 warhead)
$236,504 (TV guidance with BLU-109 warhead)
$238,961 (IR guidance with BLU-109 warhead)

Deployed Date: 1983 (GBU-15)
2000 (EGBU-15)

Delivery Aircraft: F-15E

Contractor: Boeing

The GBU-15 glides its 2,000-pound warhead to the target.
Photo courtesy of the U.S. Air Force Museum.

Military Nomenclature: GBU-16

Name: 1,000 lb. Paveway II Laser-Guided Bomb

Description: A member of the Paveway II series of laser-guided bombs, the GBU-16 consists of a MK-83 1,000-pound general-purpose bomb mated with a Paveway II laser guidance kit. The kit includes a nose-mounted laser guidance and control group and an airfoil group, which includes canards (small wings mounted on the nose) and tail-mounted flight stability fins. The canards, which deploy after release from the aircraft, react to commands from the onboard guidance system to steer the weapon to a target illuminated by an external laser source. The bomb does not ride down the laser beam as is often thought. Instead, the seeker uses the laser spot reflecting off the target as a reference point to stay on course (the guidance unit keeps the laser spot in the center of its field of view).

The basic process of a laser-guided bomb engagement is as follows: the delivery aircraft, a second aircraft, an unmanned aerial vehicle, or a person on the ground projects a laser onto the target (known as laser "designation"); the pilot activates the seeker head in the guidance unit of the laser-guided bomb; the pilot releases the laser-guided bomb at an altitude and angle

that will give it sufficient speed and range to reach the target; the guidance unit keeps the laser spot centered in the seeker's field of view by moving the weapon's canards to steer the bomb to the target (the laser spot).

Planners use the GBU-16 against both mobile and fixed targets.

Employment Considerations: Lasers cannot penetrate clouds. Highly accurate in fair weather, laser-guided bombs don't work well when bad weather obscures the target.

To achieve maximum accuracy, aircraft crews drop laser-guided bombs at altitudes from 15,000 to 23,000 feet (known as the mid-altitude range). A mid-altitude range release gives the crew maximum opportunity to identify and "designate" the target with the targeting laser. The mid-altitude range also gives the weapon's steering fins ample time to adjust the bomb's flight and strike the target. If necessary, however, the crew can drop laser-guided bombs at low level.

The U.S. military measures bomb accuracy using a calculation known as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The GBU-16 has a CEP of 30 feet.

General Characteristics:

Speed: 5 miles. Actual range depends on release altitude.
Length: 12 feet 1 inch
Diameter: 13.8 inches
Weight: 1,092 pounds
Warhead: : The MK-83 contains 445 pounds of H-6, PBXN-109, or Tritonal explosive.
Guidance System: To guide itself to the target, the GBU-16 uses a Paveway II guidance system. The Paveway features a front-end guidance unit that acquires the reflected laser energy from a target illuminated by an external laser source. The laser designator (the external laser source) and the laser seeker in the Paveway system use pulse coding to ensure the GBU-16 tracks the correct target. The coding system uses the numbers one through eight set in three to four digit codes. The designator and the seeker must share the same code to work in harmony and guide the bomb. This system allows simultaneous attacks against multiple targets with laser guided weapons and pre-

vents the enemy from using another laser designator to lure the bomb off target. The laser receiver in the guidance unit derives the target location by using an array of photodiodes to sense reflecting laser energy. To stay on target, the sensor keeps the laser spot in the center of its field of view. When the laser spot moves off center, the guidance computer fully deflects the canards to keep the laser spot in the center of the sensor's field of view. This combination of an "on-off" seeker and hard-over movement of controls is called "bang-bang" guidance. It works well at high speed, but accuracy decreases as the weapon's speed decreases.

Control: The GBU-16 deploys its tail-mounted wings, which provide additional lift and aerodynamic stability, after release from the aircraft. The canards react to commands from the onboard guidance system to steer the weapon to a target illuminated by an external laser source.

Propulsion: None

Unit Cost: $178,000

Date Deployed: 1976

Launch Aircraft: A-10, B-52H, F-14, F-15E, F-16, F/A-18, and the F-117.

Contractor: Lockheed Martin and Raytheon

Aviation ordnancemen prepare to load a GBU-16 laser-guided bomb on an F/A-18 Hornet.
Photo courtesy of the Department of Defense.

Military Nomenclature: GBU-24

Name: 2,000 lb. Paveway III Laser-Guided Bomb

Description: The GBU-24 consists of a MK-84 2,000-pound general-purpose bomb, BLU-109 penetrator bomb, or BLU-116 penetrator bomb mated with a Paveway III laser guidance kit. The kit includes a nose mounted laser guidance and control group and an airfoil group, which includes canards (small wings mounted on the nose) and tail-mounted flight stability fins. The canards react to commands from the onboard guidance system to steer the weapon to a target illuminated by an external laser source. The bomb does not ride down the laser beam as is often thought. Instead, the seeker uses the laser spot reflecting off the target as a reference point to stay on course (the guidance unit keeps the laser spot in the center of its field of view).

The basic process of a laser-guided bomb engagement is as follows: the delivery aircraft, a second aircraft, an unmanned aerial vehicle, or a person on the ground projects a laser onto the target (known as laser "designation"); the pilot activates the seeker head in the guidance unit of the laser-guided bomb; the pilot releases the laser-guided bomb at an altitude and angle that will give it sufficient speed and range to reach the target; the guidance unit keeps the laser spot centered in the seeker's field of view by moving the weapon's canards to steer the bomb to the target (the laser spot).

Planners use the GBU-24 against both mobile and fixed soft and hard targets.

Employment Considerations: Lasers cannot penetrate clouds. Highly accurate in fair weather, laser guided bombs don't work well when bad weather obscures the target. The GBU-24E/B incorporates GPS/INS guidance with its laser guidance unit to overcome this obstacle. Should clouds, fog, or smoke cause a complete loss of laser designation, the GPS/INS package will guide the weapon to the target.

To achieve maximum accuracy, aircraft crews drop laser-guided bombs at altitudes from 15,000 to 23,000 feet (known as the mid-altitude range). A mid-altitude range release gives the crew maximum opportunity to identify and "designate" the target with the targeting laser. The mid-altitude range also gives the weapon's steering fins ample time to adjust the bomb's flight and strike the target.

The U.S. military measures bomb accuracy using a calculation known as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The GBU-24 has a CEP of 30 feet.

General Characteristics:

Range: 12 miles. Actual range depends on release altitude.
Length: 14 feet 5 inches
Diameter: 1 foot 6 inches
Weight: 2,315 pounds (MK-84 variant)
2,350 pounds (BLU-109 variant)
Warhead: The GBU-24 can carry a number of warheads. The 2,000-pound MK-84 general-purpose bomb contains 945 pounds of H-6 or Tritonal explosive. It destroys its target through traditional blast and fragmentation. The BLU-109 has a one-inch thick case made of high-strength steel designed to penetrate hardened structures. The bomb contains 550 pounds of Tritional explosive and uses a tail-mounted, time-delay fuze to detonate the warhead after penetration. When equipped with the Hard-Target Smart Fuze (HTSF), the BLU-109 will detonate at a specified depth, which greatly increases its lethality when attacking underground structures or buildings. The BLU-116 Advanced Unitary Penetrator (AUP) has a narrow case made of a tough nickel-cobalt steel alloy that gives it twice the penetration capability of the BLU-109. The use of heavy metals in the BLU-116 reduces the bomb's explosive payload, which reduces collateral damage when attacking targets such as stored nuclear, biological, or chemical agents.
Guidance System: To guide itself to the target, the GBU-24 uses a Paveway III guidance system. The Paveway III features a front-end guidance unit that acquires the reflected laser energy from a target illuminated by an external laser source. The Paveway III seeker has a wider field of view and greater sensitivity than its predecessors. While the Paveway II guidance unit can only fully deflect its canards (known as bang-bang guidance), the Paveway III guidance unit can deflect its canards incrementally to bring the laser spot back to the center of the seeker's field of view (known as proportional guidance). Proportional guidance improves performance of the weapon during flight and gives the pilot a larger delivery envelope. Earlier Paveway laser guided bombs

required strict release parameters to solve speed and wind drift problems. The GBU-24E/B, an Enhanced Paveway Laser-Guided Bomb, integrates GPS/INS guidance with the existing Paveway III laser guidance to produce the precision needed to destroy underground bunkers.

Control: The GBU-24 employs an airfoil group, which includes nose-mounted canards and tail-mounted flight stability fins. To improve its standoff range and modes of delivery, the GBU-24 has larger fins than the Paveway I and II series of laser-guided bombs. The nose-mounted canards react to commands from the onboard guidance system to steer the weapon to the target illuminated by an external laser source.

Propulsion: None

Unit Cost: $53,933 to $65,199

Date Deployed: 1983 (GUB-24)
2000 (EGBU-24)

Delivery Aircraft: A-10, F-14, F-15E, F-16, and the F/A-18.

Contractor: Raytheon

An Airman loads a GBU-24 laser guided bomb on an F-15 Eagle. *Photo courtesy of the Department of Defense.*

Military Nomenclature: GBU-27

Name: Have Void

Description: TThe GBU-27 is a BLU-109, a 2,000-pound bomb designed to penetrate hard targets, mated with a Paveway III laser guidance unit and Paveway II fins. The nose-mounted Paveway III laser guidance unit includes canards (small wings) that react to commands from the onboard guidance system to steer the weapon to a target illuminated by an external laser source. The tail-mounted Paveway II flight stability fins provide additional lift. The bomb does not ride down the laser beam as is often thought. Instead, the seeker uses the laser spot reflecting off the target as a reference point to stay on course (the guidance unit keeps the laser spot in the center of its field of view).

The basic process of a laser-guided bomb engagement is as follows: the delivery aircraft, a second aircraft, an unmanned aerial vehicle, or a person on the ground projects a laser onto the target (known as laser "designation"); the pilot activates the seeker head in the guidance unit of the laser-guided bomb; the pilot releases the laser-guided bomb at an altitude and angle that will give it sufficient speed and range to reach the target; the guidance unit keeps the laser spot centered in the seeker's field of view by moving the weapon's canards (mounted on the nose) to steer the bomb to the target (the laser spot).

The F-117 stealth fighter uses the GBU-27 to destroy targets such as command and control bunkers (it can penetrate up to six feet of reinforced concrete).

Employment Considerations: Lasers cannot penetrate clouds. Highly accurate in fair weather, laser guided bombs don't work well when bad weather obscures the target.

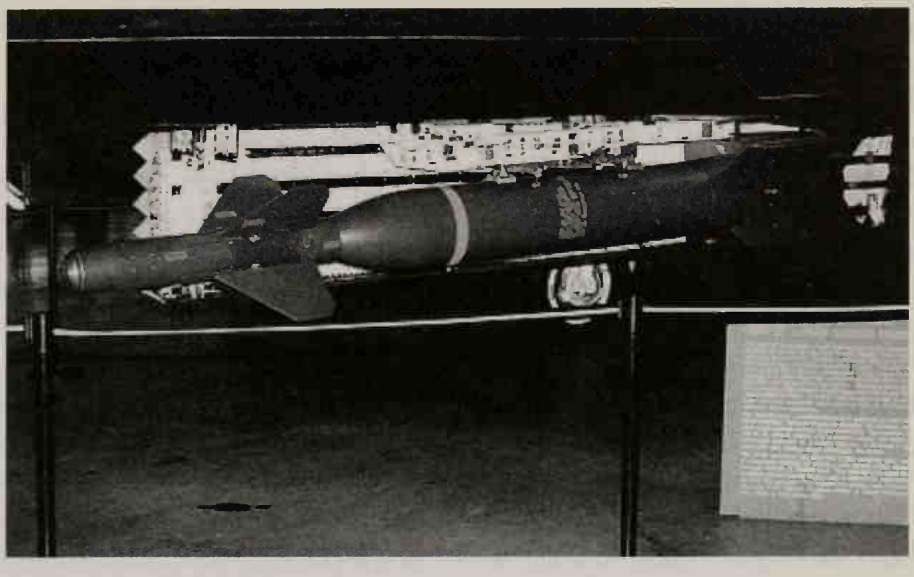
To achieve maximum accuracy, aircraft crews drop laser-guided bombs at altitudes from 15,000 to 23,000 feet (known as the mid-altitude range). A mid-altitude range release gives the crew maximum opportunity to identify and "designate" the target with the targeting laser. The mid-altitude range also gives the weapon's steering fins ample time to adjust the bomb's flight and strike the target.

The U.S. military measures bomb accuracy using a calculation known

as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The GBU-27 has a CEP of 30 feet.

General Characteristics:

Range: More than 8 miles. Actual range depends on release altitude.
Length: 13 feet 11 inches
Diameter: 1 foot 2.5 inches
Weight: 2,170 pounds
Warhead: The BLU-109 has a one-inch thick case made of high-strength steel designed to penetrate hardened structures. The bomb contains 550 pounds of Tritional explosive and uses a tail-mounted, time-delay fuze to detonate the warhead after penetration.
Guidance System: To guide itself to the target, the GBU-27 uses a Paveway III guidance system. The Paveway III features a front-end guidance unit that acquires the reflected laser energy from a target illuminated by an external laser source. The Paveway III seeker has a wider field of view and greater sensitivity than its predecessors. While the Paveway II guidance unit can only fully deflect its canards (known as bang-bang guidance), the Paveway III guidance unit can deflect its canards incrementally to bring the laser spot back to the center of the seeker's field of view (known as proportional guidance). Proportional guidance improves the performance of the weapon during flight and gives the pilot a larger delivery envelope. Earlier Paveway laser guided bombs required strict release parameters to solve speed and wind drift problems. The Paveway III can shape the terminal trajectory of the GBU-27 to create the optimum impact angle against the target – it will strike a target such as an aircraft shelter at a vertical angle but fly a horizontal approach to strike a bridge support.
Control: The GBU-27 employs an airfoil group, which includes canards (small wings mounted on the nose) and tail-mounted flight stability fins. The canards react to commands from the onboard guidance system to steer the weapon to the target illuminated by an external laser source.
Propulsion: None
Unit Cost: $62,774
Date Deployed: 1987
Delivery Aircraft: F-117 and the B-1B.
Contractor: Raytheon



A GBU-27 displayed at the USAF Museum.
Photo courtesy of the U.S. Air Force Museum.

Military Nomenclature: GBU-28

Name: Bunker Buster

Description: A laser-guided bomb designed to destroy hardened targets such as command and control centers buried underground, the GBU-28 uses the BLU-113, a 4,400-pound bomb, as its warhead. Engineers have mated the massive bomb with a Paveway III laser guidance unit and Paveway II fins to produce a massive precision guided munition. The nose-mounted Paveway III laser guidance unit includes canards (small wings) that react to commands from the onboard guidance system to steer the weapon to a target illuminated by an external laser source. The tail-mounted Paveway II flight stability fins provide additional lift. The bomb does not ride down the laser beam as is often thought. Instead, the seeker uses the laser spot reflecting off the target as a reference point to stay on course (the guidance unit keeps the laser spot in the center of its field of view).

The basic process of a laser-guided bomb engagement is as follows:

the delivery aircraft, a second aircraft, an unmanned aerial vehicle, or a person on the ground projects a laser onto the target (known as laser "designation"); the pilot activates the seeker head in the guidance unit of the laser-guided bomb; the pilot releases the laser-guided bomb at an altitude and angle that will give it sufficient speed and range to reach the target; the guidance unit keeps the laser spot centered in the seeker's field of view by moving the weapon's canards (small wings mounted on the nose) to steer the bomb to the target (the laser spot).

The GBU-28 can penetrate more than 20 feet of concrete or more than 100 feet of earth.

Employment Considerations: Lasers cannot penetrate clouds. Highly accurate in fair weather, laser guided bombs don't work well when bad weather obscures the target.

To achieve maximum accuracy, aircraft crews drop laser-guided bombs at altitudes from 15,000 to 23,000 feet (known as the mid-altitude range). A mid-altitude range release gives the crew maximum opportunity to identify and "designate" the target with the targeting laser. The mid-altitude range also gives the weapon's steering fins ample time to adjust the bomb's flight and strike the target.

The U.S. military measures bomb accuracy using a calculation known as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The GBU-28 has a CEP of 30 feet.

General Characteristics:

Range: 6 miles. Actual range depends on release altitude.
Length: 19 feet 1 inches
Diameter: 1 foot 2.5 inches
Weight: 4,700 pounds
Warhead: The GBU-28 uses the BLU-113 as its warhead. A 4,400-pound bomb made from surplus 8-inch artillery tubes, the BLU-113 contains 630 pounds of Tritonal high explosive. Designed to penetrate hardened targets, it employs a tail fuze to detonate the bomb after it has knifed its way deep into the heart of its target. The bomb can penetrate 20 feet of concrete or more than 100 feet of earth.
Guidance System: To guide itself to the target, the GBU-28 uses a Paveway

III guidance system. The Paveway III features a front-end guidance unit that acquires the reflected laser energy from a target illuminated by an external laser source. The Paveway III seeker has a wider field of view and greater sensitivity than its predecessors. While the Paveway II guidance unit can only fully deflect its canards (known as bang-bang guidance), the Paveway III guidance unit can deflect its canards incrementally to bring the laser spot back to the center of the seeker's field of view (known as proportional guidance). Proportional guidance improves performance of the weapon during flight and gives the pilot a larger delivery envelope. Earlier Paveway laser guided bombs required strict release parameters to solve speed and wind drift problems. The Paveway III can shape the terminal trajectory of the GBU-28 to create the optimum impact angle against the target – it will strike a target such as an underground command and control facility at a vertical angle but fly a horizontal approach to strike a bridge support.

The Air Force has added GPS guidance to a few GBU-28s to improve their accuracy. These enhanced bombs are designated the EGBU-28. The B-2 employs the EGBU-28.

Control: The GBU-28 employs an airfoil group which includes canards (small wings mounted on the nose) and tail-mounted flight stability fins. The canards react to commands from the onboard guidance system to steer the weapon to the target illuminated by an external laser source.

Propulsion: None

Unit Cost: $131,874 (GBU-28)

Date Deployed: 1991

Delivery Aircraft: The F-15E is the only aircraft in the inventory certified to deliver the GBU-28. The B-2 bomber delivers the EGBU-28.

Contractor: Raytheon

An aircrew inspects a GBU-28 prior to a mission.
Photo courtesy of the U.S. Air Force.

Military Nomenclature: GBU-31

Name: 2,000 lb. Joint Direct Attack Munition (JDAM)

Description: A MK-84 general-purpose bomb or BLU-109 penetrating warhead bomb mated with a Joint Direct Attack Munition (JDAM) kit. The JDAM kit consists of a Global Positioning System (GPS) receiver, a guidance computer that couples both Global Positioning System (GPS) and Inertial Navigation System (INS) navigation, and adjustable airfoil fins that give the bomb guidance capability. The guidance computer uses the GPS (which determines location by using satellite signals) and the INS (which employs instrumentation to detect changes in relative positions) to determine its location and guide the bomb to preprogrammed geographical coordinates. The target coordinates can be entered at any time before weapon release or automatically entered through target designation with onboard aircraft sensors. Once released from the aircraft the bomb operates autonomously without further input from the aircraft crew. The GBU-31 can operate in all weather conditions.

Planners use the GBU-31 against high priority fixed targets. It does not have the capability to strike moving targets.

Employment Considerations: To achieve maximum accuracy, aircraft crews drop precision-guided bombs at altitudes from 15,000 to 23,000 feet (known as the mid-altitude range). A mid-altitude range release gives the weapon's steering fins ample time to adjust the bomb's flight and strike the target.

The U.S. military measures bomb accuracy using a calculation known as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The GBU-32 has a CEP of 39 feet (operational use has shown that most bombs land within ten feet of the intended target) when both the GPS and INS modes operate properly.

Should an enemy manage to jam the GPS signal, the JDAM will still travel to the target under guidance from the INS. In INS mode only, the JDAM has a CEP of 90 feet.

The current JDAM's (the 2,000-pound GBU-31 and the 1,000-pound GBU-32) sheer size and destructive power make their use in urban areas and in tactical situations such as close air support problematic. Planners and aircrew face a high risk of unwanted collateral damage. The 500-pound GBU-

30 (scheduled for deployment in 2004) and the planned 250-pound GBU-29 will alleviate many of these problems.

If a laser guided bomb loses its lock on the targeting laser it can land a mile or more off target. If the JDAM's GPS system fails, the bomb's inertial system will guide the target to within 90 feet of the target.

General Characteristics:

Range: Up to 15 miles depending on release altitude.
Length: Varies between 12 feet 4.6 inches to 12 feet 8.7 inches
Diameter: 1 foot 6 inches (MK-84)
1 foot 2.5 inches (BLU-109)
Weight: Varies beween 2,036 pounds to 2,115 pounds
Warhead: The 2,000-pound MK-84 general-purpose bomb contains 945 pounds of H-6 or Tritonal explosive. It destroys its target through traditional blast and fragmentation. The BLU-109 has a one-inch thick case made of high-strength steel designed to penetrate hardened structures. The bomb contains 550 pounds of Tritional explosive and uses a tail-mounted, time-delay fuze to detonate the warhead after penetration.
Guidance System: The guidance computer uses GPS signals to determine its location and guide the bomb to preprogrammed geographical coordinates. Planners derive these "geocoordinates" by fusing reconnaissance imagery with three-dimensional terrain data, a process called mensuration. The process results in a Desired Mean Point of Impact (DMPI), which is fed into the guidance computer prior to release from the delivery aircraft. The target coordinates can also be added manually during the mission or automatically entered through target designation with onboard aircraft sensors. After release from the aircraft, the bomb's GPS/INS will guide the bomb to the target. Should the GPS cease to function for whatever reason (such as enemy jamming of the GPS signal), the Inertial Navigation System (INS) will guide the weapon.
Control: Like other precision-guided munitions, the GBU-31 has tail fins that move on command. By manipulating the fins in flight, the guidance system can alter the bomb's course and home on targets. It also has mid-body strakes attached to the bomb body to enhance weapon maneuverability and range.
Propulsion: None
Unit Cost: $29,329 (MK-84)
$37,030 (BLU-109)

Date Deployed: 1997
Delivery Aircraft: AV-8B, B-1B, B-2, B-52H, F-14, F-15E, F-16, F/A-18, F/A-22, F-117, P-3C, and the S-3B.
Contractor: Boeing

A hard-target BLU-109 warhead mated with a JDAM kit prepared for loading aboard a B-1B bomber. *Photo courtesy of the USAF.*

Military Nomenclature: GBU-32

Name: 1,000 lb Joint Direct Attack Munition (JDAM)

Description: A MK-83 or BLU-110 general-purpose bomb mated with a Joint Direct Attack Munition (JDAM) kit. The JDAM kit consists of a Global Positioning System (GPS) receiver, a guidance computer that couples both Global Positioning System (GPS) and Inertial Navigation System (INS) navigation, and adjustable airfoil fins that give the bomb guidance capability. The guidance computer uses GPS (which determines location by using satellite signals) and the INS (which employs instrumentation to detect changes in relative positions) to determine its location and guide the bomb to preprogrammed geographical coordinates. The target coordinates can be entered at any time before weapon release or automatically entered through target designation with onboard aircraft sensors. Once released from the aircraft, the bomb operates autonomously without further input from the aircraft crew. The GBU-32

can operate in all weather conditions.

Planners use the GBU-32 against high priority fixed targets. It does not have the capability to strike moving targets.

Employment Considerations: To achieve maximum accuracy, aircraft crews drop JDAMs at altitudes from 15,000 to 23,000 feet (known as the mid-altitude range). A mid-altitude range release gives the weapon's steering fins ample time to adjust the bomb's flight and strike the target.

The U.S. military measures bomb accuracy using a calculation known as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The GBU-32 has a CEP of 39 feet when both the GPS and INS modes operate properly. Should an enemy manage to jam the GPS signal, the JDAM will still travel to the target under guidance from the INS. In INS mode only, the JDAM has a CEP of 90 feet.

The current JDAMs (the 2,000-pound GBU-31 and the 1,000-pound GBU-32) sheer size and destructive power make their use in urban areas and in tactical situations such as close air support problematic. Planners and aircrew face a high risk of unwanted collateral damage. The 500-pound GBU-30 (scheduled for deployment in 2004) and the planned 250-pound GBU-29 will alleviate many of these problems.

If a laser-guided bomb loses its lock on the targeting laser it can land a mile or more off target. If the JDAM's GPS system fails, the bomb's inertial system will guide the target to within 90 feet of the target.

General Characteristics:

Range: Up to 15 miles depending on release altitude.
Length: 9 feet 11.5 inches
Diameter: 1 foot 2 inches
Weight: 1,013 pounds
Warhead: The GBU-32 uses the MK-83, a 1,000-pound, general-purpose bomb, as its warhead. It contains 445 pounds of H-6, PBXN-109, or Tritonal explosive and destroys its target with blast and fragmentation. A variety of mechanical (impact) nose and tail fuzes and electrical fuzes (used to explode the bomb in the air above the target) can denote the bomb. The BLU-110 is a MK-83 general-purpose bomb filled with PBXN-109, an explosive less sensitive to heat than traditional explosives. This characteristic increases the time the

bomb can spend in a fuel fire before explosion, an important feature aboard an aircraft carrier. The re-designation as BLU-110 alerts ordnance personnel to the bomb's thermal protection.

Guidance System: The guidance computer uses GPS signals to determine its location and guide the bomb to preprogrammed geographical coordinates. Planners derive these "geocoordinates" by fusing reconnaissance imagery with three-dimensional terrain data, a process called mensuration. The process results in a Desired Mean Point of Impact (DMPI) which is fed into the guidance computer prior to release from the delivery aircraft. The target coordinates can also be added manually during the mission or automatically entered through target designation with onboard aircraft sensors. After release from the aircraft, the bomb's GPS/INS will guide the bomb to the target. Should the GPS cease to function for whatever reason (such as enemy jamming of the GPS signal), the Inertial Navigation System (INS) will guide the weapon.

Control: Like other precision-guided munitions, the GBU-32 has tail fins that move on command. By manipulating the fins in flight, the guidance system can alter the bomb's course and home on targets. It also has mid-body strakes attached to the bomb body to enhance weapon maneuverability and range.

Propulsion: None

Unit Cost: $23,138

Date Deployed: 1997

Delivery Aircraft: AV-8B, B-1B, B-2, B-52H, F-14, F-15E, F-16, F/A-18, F/A-22, F-117, P-3C, and the S-3B.

Contractor: Boeing

JDAM bombs mounted on the wing of a B-52H bomber.
Photo courtesy of the USAF.

CHAPTER 5: Cluster Munitions

Military Nomenclature: MK-20

Name: Rockeye

Description: A cluster munition that evenly scatters anti-tank submunitions in an elliptical pattern that covers an area of more than 30,000 square feet. The MK-20 consists of a clamshell dispenser filled with 247 MK-118 anti-tank bomblets. Upon release from the aircraft, the arming wire pulls free from the dispenser's mechanical delay fuze (the pilot can select a delay of 1.2 or 4 seconds) and the spring-actuated tail fins snap open. The delay fuze detonates two linear-shaped charges that cut the dispenser in half, scattering the bomblets into the wind. The anti-tank bomblets explode on impact and can penetrate about 7.5 inches of armor.

Employment Considerations: Cluster munition bomblets have a high dud rate -usually around 5 percent fail to explode on impact - and can scatter unexploded ordnance over a large area.

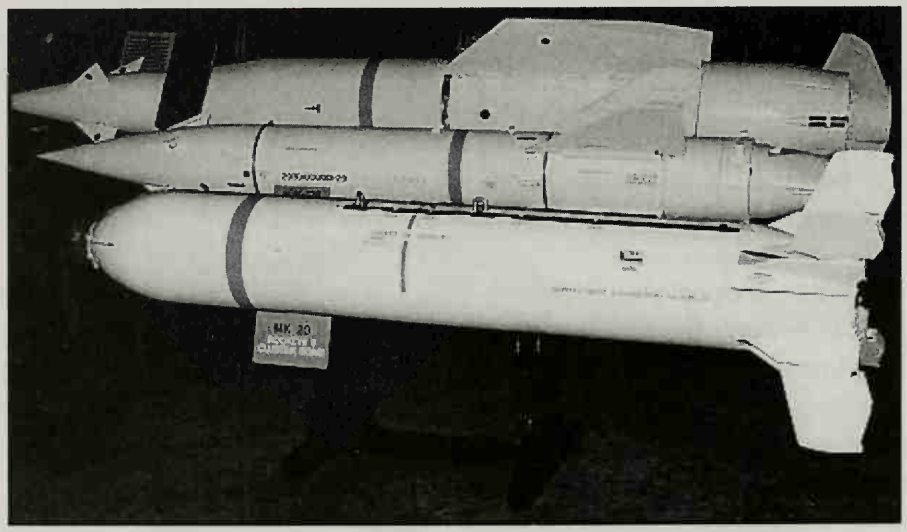
Because a single cluster bomb will cover a wide area, it will cause massive collateral damage if used in or near an area inhabited by civilian personnel.

When shaped charges strike an armored vehicle they punch a very small hole through the hull and kill the crew and destroy the vehicle through spalling (metal fragments shear off the inside wall as the charge blows through the hull and bounce around inside the vehicle). This process leaves little evidence of vehicle destruction and often leads to multiple aerial attacks on a previously destroyed vehicle.

General Characteristics:

Range: Varies depending on release altitude.

Length: 6 feet 11 inches
Diameter: 13 inches
Weight: 476 pounds
Dispenser: MK 7
Warhead: The dart-shaped MK-117 anti-tank bomblet measures 2.1 inches in length and 1.9 inches in diameter and weighs 1.32 pounds. An impact fuze detonates the bomblet's small shaped charge capable of penetrating 7.5 inches of armor.
Guidance System: Ballistic
Control: Four spring-actuated folding fins mounted on the tail assembly pop open after release from the aircraft.
Propulsion: None
Unit Cost: $3,711
Date Deployed: 1968
Delivery Aircraft: A-10, B-52H, F-14, F-15E, F-16, F/A-18, and F-117.
Contractor: Inventory



A MK-20 Rockeye cluster bomb (foreground) displayed at the USAF Museum. Photo courtesy of the U.S. Air Force Museum.

Military Nomenclature: CBU-52

Name: Anti-Personnel/Anti-Material Cluster Munition

Description: The CBU-52 is a cluster bomb that dispenses 220 BLU-61 bomblets in a donut-like pattern - a circle with a hole in the middle. The density of the bomblets within the circle depends on many factors such as wind speed. The bomb consists of a cigar-shaped SUU-30 dispenser divided in half longitudinally and locked together. Four aluminum fins mounted at the rear of the canister give the bomb spin-stabilized flight once released from the aircraft. Upon release from the aircraft, an arming wire pulls free from the fuze and starts the time delay to detonation. When the fuze fires, it forces open the front end of the canister. Air ramming into the open mouth of the canister instantly rips open the canister halves and scatters the BLU-61 bomblets. The BLU-61 bomblets spin arm (after spinning a certain number of times the fuzes arm themselves) and scatter in the wind. The bomblets produce fragmentation capable of destroying personnel and light skinned vehicles. Planners normally use the CBU-52 against targets such as anti-aircraft sites, artillery emplacements, radar sites, and troops in the open.

Employment Considerations: Cluster munition bomblets have a high dud rate -usually around 5percent fail to explode on impact - and can scatter unexploded ordnance over a large area.

Because a single cluster bomb will cover a wide area, it will cause massive collateral damage if used in or near an area inhabited by civilian personnel.

General Characteristics:

Range: Varies depending on release altitude.
Length: 7 feet 2 inches
Diameter: 1 foot 4 inches
Weight: 768 pounds
Dispenser: SUU-30H/B
Warhead: A 3.5 inch spherical bomblet, the BLU-61 weighs 2.7 pounds and contains 0.65 pounds of high explosive. After release from the cluster bomb

dispenser, the bomblet arms itself after spinning a number of times. Flutes on the bomblet cause it to spin which also generates lift (called the Magnus Effect) that helps it disperse over the target area. It will accept a variety of proximity fuzes (used to explode the bomblet in the air above a target area) and a mechanical delay fuze. The BLU-61 can destroy troops and soft skinned targets.

Guidance System: Ballistic

Control: The SUU-30 dispenser has four aluminum fins attached on its aft end. Attached at a 9-degree angle and canted 1.25 degrees, the fins spin stabilize the dispenser after release from the aircraft.

Propulsion: None

Unit Cost: $1,659.00

Date Deployed: Vietnam War

Delivery Aircraft: A-10, F-15E, F-16, B-52H, and F-117.

Contractor: Inventory

Air Force troops stack CBU-58 cluster bombs during Operation Desert Storm. The CBU-52 uses the same dispenser - the SUU-30 - as the CBU-58, CBU-71, and the LBU-30. Photo courtesy of the US Air Force.

Military Nomenclature: CBU-58

Name: Anti-Personnel/Anti-Material (APAM) Cluster Bomb

Description: The CBU-58 is a cluster bomb that dispenses 650 BLU-63 bomblets in a donut-like pattern - a circle with a hole in the middle. The density of the bomblets within the circle depends on many factors such as wind speed. The bomb consists of a cigar-shaped SUU-30 dispenser divided in half longitudinally and locked together. Four aluminum fins mounted at the rear of the canister give the bomb spin-stabilized flight once released from the aircraft. Upon release from the aircraft, an arming wire pulls free from the fuze and starts the time delay to detonation. When the fuze fires, it forces open the front end of the canister. Air ramming into the open mouth of the canister instantly rips open the canister halves and scatters the BLU-63 bomblets. The BLU-63 bomblets spin arm (after spinning a certain number of times the fuzes arm themselves) and scatter in the wind. Designed to explode upon impact, the BLU-63 can deliver fragmentation and incendiary effects on the target area. Planners normally use the CBU-58 against targets such as anti-aircraft sites, artillery emplacements, radar sites, armored personnel carriers, and troops in the open.

Employment Considerations: Cluster munition bomblets have a high dud rate -usually around five percent fail to explode on impact - and can scatter unexploded ordnance over a large area.

Because a single cluster bomb will cover a wide area, it will cause massive collateral damage if used in or near an area inhabited by civilian personnel.

General Characteristics:

Range: Varies depending on release altitude.
Length: 7 feet 6 inches
Diameter: 1 foot 4 inches
Weight: about 820 pounds
Dispenser: SUU-30H/B
Warhead: The CBU-58 delivers 650 BLU-63 bomblets on the target area. The

BLU-63 bomblet spin arms and explodes on impact. Flutes on the bomblet cause it to spin which also generates lift (called the Magnus Effect) that helps it disperse over the target area. The BLU-63/B delivers only fragmentation on the target. Its scored steel casing produces about 260 fragments upon detonation. The BLU-63A/B produces both fragmentation and incendiary effects. To produce the incendiary effects, the bomblet employs two 5-gram titanium pellets. Each bomblet has a diameter of about three inches, weighs about a pound, and contains approximately .25 pounds of explosive.
Guidance System: Ballistic
Control: Four aluminum fins mounted at the rear of the canister give the bomb spin-stabilized flight once released from the aircraft.
Propulsion: None
Unit Cost: $2,352
Date Deployed: Vietnam War
Delivery Aircraft: A-10, B-52H, F-15E, F-16, and F-117.
Contractor: Inventory

A B-1B bomber drops cluster munitions. Note the canisters beginning to open at the bottom of the photograph. Photo courtesy of the Department of Defense.

Military Nomenclature: CBU-59B

Name: Rockeye II

Description: The Rockeye II is an updated version of the MK-20 Rockeye cluster munition. The CBU-59 consists of a clamshell-shaped dispenser holding 717 BLU-77 bomblets. The dart-shaped bomblets explode on impact and have combined anti-armor, antipersonnel, and incendiary features. The dispenser scatters the bomblets over a large area. A delivery aircraft can deploy Rockeye at high speeds and low levels.

Employment Considerations: Cluster munition bomblets have a high dud rate - usually around 5 percent fail to explode on impact - and can scatter unexploded ordnance over a large area.

Because a single cluster bomb will cover a wide area, it will cause massive collateral damage if used in or near an area inhabited by civilian personnel.

The CBU-59 has a minimum release altitude of 500 feet above ground level (AGL).

When shaped charges strike an armored vehicle they punch a very small hole through the hull and kill the crew and destroy the vehicle through spalling (metal fragments shear off the inside wall as the charge blows through the hull and bounce around inside the vehicle). This process leaves little evidence of vehicle destruction and often leads to multiple aerial attacks on a previously destroyed vehicle.

General Characteristics:

Range: Varies depending on release altitude.
Length: 6 feet 11 inches
Diameter: 13 inches
Weight: 750 pounds
Dispenser: Mk 7
Warhead: The dart-shaped BLU-77 bomblet has combined anti-armor, antipersonnel, and incendiary effects.
Guidance System: Ballistic
Control: Four spring-actuated folding fins mounted on the tail assembly pop

open after release from the aircraft.
Propulsion: None
Unit Cost: Inventory
Date Deployed: 1970s
Delivery Aircraft: A-10, B-52H, F-14, F-15E, F-16, F/A-18, and F-117.
Contractor: Inventory

Ordnancemen manhandle a cart of Rockeye cluster bomb dispensers. The MK-20 Rockeye and the CBU-59 APAM cluster bombs use the same dispenser. Photo courtesy of the Department of Defense.

Military Nomenclature: CBU-71

Name: Anti-Personnel/Anti-Material Cluster Munition

Description: The CBU-71 is a cluster bomb that dispenses 650 BLU-68/B bomblets in a donut-like pattern - a circle with a hole in the middle. The den-

sity of the bomblets within the circle depends on many factors such as wind speed. The bomb consists of a cigar-shaped SUU-30 dispenser divided in half longitudinally and locked together. Four aluminum fins mounted at the rear of the canister give the bomb spin-stabilized flight once released from the aircraft. Upon release from the aircraft, an arming wire pulls free from the fuze and starts the time delay to detonation. When the fuze fires, it forces open the front end of the canister. Air ramming into the open mouth of the canister instantly rips open the canister halves and scatters the BLU-68 bomblets. The BLU-68 bomblets spin arm (after spinning a certain number of times the fuzes arm themselves) and scatter in the wind. The disk-shaped bomblets produce both fragmentation and incendiary effects and use a time delay fuze to detonate at random intervals after impact. The majority of bomblets explode within eight seconds of impact. Planners use the CBU-71 against soft targets such as fuel storage facilities, ammunition storage sites, and light-skinned vehicles.

Employment Considerations: Cluster munition bomblets have a high dud rate - usually around 5 percent fail to explode on impact - and can scatter unexploded ordnance over a large area.

Because a single cluster bomb will cover a wide area, it will cause massive collateral damage if used in or near an area inhabited by civilian personnel.

General Characteristics:

Range: Varies depending on release altitude.
Length: 7 feet 2 inches
Diameter: 1 foot 4 inches
Weight: 818 pounds
Dispenser: SUU-30H/B
Warhead: The CBU-71 delivers 650 BLU-68/B bomblets on the target area. Each disk-shaped bomblet has a diameter of about three inches and weighs about a pound. The BLU-68/B bomblet spin arms and uses a time delay fuze to detonate at random intervals after impact. Flutes on the bomblet cause it to spin which also generates lift (called the Magnus Effect) that helps it disperse over the target area. Most of the bomblets detonate within eight seconds of impact. The BLU-68/B produces both fragmentation and incendiary effects.
Guidance System: Ballistic

Control: Four aluminum fins mounted at the rear of the canister give the bomb spin-stabilized flight once released from the aircraft.
Propulsion: None
Unit Cost: $4,071
Date Deployed: Vietnam War
Delivery Aircraft: A-10, B-52H, F-15E, F-16, and F-117.
Contractor: Inventory

Air Force troops stack CBU-58 cluster bombs during Operation Desert Storm. The CBU-71 uses the same dispenser - the SUU-30 - as the CBU-52, CBU-58, and the LBU-30. Photo courtesy of the US Air Force.

Military Nomenclature: CBU-72

Name: Fuel/Air Explosive

Description: The CBU-72 cluster bomb consists of a SUU-19B dispenser that holds three BLU-73B fuel/air explosive (FAE) submunitions. Each submuition holds about 75 pounds of ethylene oxide and has an airburst fuze set to detonate at 30 feet. On detonation, the submunitions dispense their ethylene oxide into the wind forming a 60 feet in diameter and eight feet thick aerosol cloud.

A delayed detonator then ignites the explosive cloud. The overpressure created by the massive explosion destroys soft targets in and near the fuel cloud. Planners typically use the CBU-72 against troops in trenches or bunkers and armored vehicles. It has also proved useful in clearing minefields.

Employment Considerations: Fuel/air explosives make excellent psychological weapons.

General Characteristics:

Range: Varies depending on release altitude.
Length: 7 feet 1.6 inches
Diameter: 1 foot 2 inches
Weight: 500 pounds
Dispenser: SUU-19B
Warhead: The BLU-73B weighs about 100 pounds and contains 75 pounds of ethylene oxide. The CBU- 72 holds three BLU-73B submunitions. Each BLU-73B has an airburst fuze set to detonate at 30 feet. On detonation, the BLU-73B dispenses its ethylene oxide into the wind forming an explosive aerosol cloud. A delayed detonator then ignites the explosive cloud.
Guidance System: Ballistic
Control: The SUU-19 has four tail fins to stabilize the dispenser after release from the delivery aircraft.
Propulsion: None
Unit Cost: Inventory
Date Deployed: Vietnam War
Delivery Aircraft: A-10, B-52H, F-15E, F-16, and F-117.

A CBU-72 displayed at the U.S. Naval Museum of Armament & Technology. Photograph courtesy of Brian Lockett and the Goleta Air & Space Museum.

Military Nomenclature: CBU-78

Name: Anti-Personnel/Anti-Material Cluster Munition

Description: Tactical aircraft drop the CBU-78 to create instant minefields. Like other members of the Gator mine system, the CBU-78 contains a mix of BLU-91/B antitank and BLU-92B antipersonnel mines. At what height the dispenser opens determines the size of the minefield. Ordnance personnel can use a proximity fuze (a fuze that detonates at a specific height above the ground) or an electomechanical fuze (a fuze that explodes after a preset time delay) to open the dispenser. The Gator mine system gives commanders a weapon that can deny the enemy key terrain, channel enemy forces into kill boxes, or trap an enemy force for later destruction.

Employment Considerations: Cluster munitions have a high dud rate - usually around five percent fail to explode - and can scatter unexploded ordnance over a large area.

Because a single cluster bomb will cover a wide area, it will cause massive collateral damage if used in or near an area inhabited by civilian personnel.

When shaped charges strike an armored vehicle they punch a very small hole through the hull and kill the crew and destroy the vehicle through spalling (metal fragments shear off the inside wall as the charge blows through the hull and bounce around inside the vehicle). This process leaves little evidence of vehicle destruction and often leads to multiple aerial attacks on a previously destroyed vehicle.

General Characteristics:

Range: Varies depending on release altitude.
Length: 6 feet 11 inches
Diameter: 13 inches
Weight: 490 pounds
Dispenser: Mk 7
Warhead: The CBU-78 contains 45 BLU-91/B antitank (AT) and 15 BLU-92/B antipersonnel mines (AP). The BLU-91/B uses a target sensor to detect mag-

netic fields. When it detects an armored vehicle passing overhead, it fires a shaped charge into the belly of the vehicle. Upon impact, the BLU-92/B AP mine deploys four trip wires up to 40 feet long. If disturbed, the AP mine explodes, sending high-velocity fragments over a wide area. The AP mines are mixed with the AT mines to discourage minefield clearance. Designed to deny the enemy use of terrain for a specific time period, both mines have time-programmable self-destruct mechanisms.
Guidance System: Ballistic
Control: Four spring-actuated folding fins mounted on the tail assembly pop open after release from the aircraft.
Propulsion: None
Unit Cost: $39,963
Date Deployed: mid-1980s
Delivery Aircraft: A-10, B-52H, F-14, F-15E, F-16, F/A-18, and F-117.
Contractor: Aerojet-General Corporation

The CBU-78 Gator uses the Mk 7 dispenser.
Photo courtesy of the US Navy.

Military Nomenclature: CBU-87

Name: Combined Effects Munition (CEM)

Description: The CBU-87 delivers 202 BLU-97/B bomblets in a rectangular pattern. The size of the rectangle and the density of bomblets within it depend on the spin rate of the dispenser (the weapon offers six spin selections) and release parameters such as the height at which the dispenser bursts open and scatters the bomblets. Ordnance personnel can use a proximity fuze (a fuze that detonates at a specific height above the ground) or an electomechanical fuze (a fuze that explodes after a preset time delay) to open the dispenser. Cylindrical in shape, the BLU-97/B measures eight inches in length and two inches in diameter. Made of scored steel designed to break into 300 fragments capable of killing soldiers or puncturing armor, the bomblet case also has a zirconium ring to produce incendiary effects. Planners use the CBU-87 against targets such as armored personnel carriers, artillery emplacements, and troops in the open.

Employment Considerations: Cluster munition bomblets have a high dud rate - usually around five percent fail to explode on impact - and can scatter unexploded ordnance over a large area.

Because a single cluster bomb will cover a wide area, it will cause massive collateral damage if used in or near an area inhabited by civilian personnel.

General Characteristics:

Range: Varies depending on release altitude.
Length: 7 feet 8 inches
Diameter: 1 foot 3.6 inches
Weight: About 950 pounds
Dispenser: SUU-65/B Tactical Munitions Dispenser
Warhead: The CBU-87B contains 202 BLU-97/B bomblets. Cylindrical in shape, the BLU-97/B measures about eight inches in length and two inches in diameter. Made of scored steel designed to break into 300 fragments capable of killing soldiers or puncturing armor, the bomblet case also has a zirconium ring to produce incendiary effects.

Guidance System: Ballistic
Control: The SUU-65/B has four tail fins that spin stabilize the dispenser after release from the delivery aircraft.
Propulsion: None
Unit Cost: $13,774.35
Date Deployed: mid-1980s
Delivery Aircraft: A-10, B-52H, B-1B, B-2, F-15E, F-16, and F/A-18.
Contractor: Aerojet-General Corporation, Honeywell, and Alliant Techsystems.

A CBU-87 cluster bomb adjacent a B-1B bomber. Photograph courtesy of the USAF.

Military Nomenclature: CBU-89

Name: Gator

Description: Tactical aircraft drop the CBU-89 to create instant minefields. Like other members of the Gator mine system, the CBU-89 contains a mix of BLU-91/B antitank and BLU-92B antipersonnel mines. At what height the dispenser opens determines the size of the minefield. Ordnance personnel can use a proximity fuze (a fuze that detonates at a specific height above the ground) or an electomechanical fuze (a fuze that explodes after a preset time delay) to open the dispenser. The Gator mine system gives commanders a weapon that

can deny the enemy key terrain, channel enemy forces into kill boxes, or trap an enemy force for later destruction.
Employment Considerations: Cluster munition bomblets have a high dud rate - usually around five percent fail to explode on impact - and can scatter unexploded ordnance over a large area.

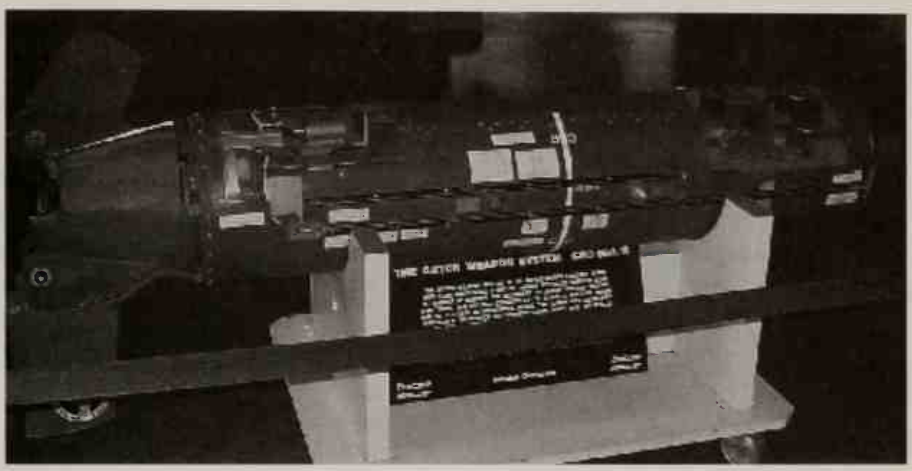
Because a single cluster bomb will cover a wide area, it will cause massive collateral damage if used in or near an area inhabited by civilian personnel.

When shaped charges strike an armored vehicle they punch a very small hole through the hull and kill the crew and destroy the vehicle through spalling (metal fragments shear off the inside wall as the charge blows through the hull and bounce around inside the vehicle). This process leaves little evidence of vehicle destruction and often leads to multiple aerial attacks on a previously destroyed vehicle.

General Characteristics:

Range: Varies depending on release altitude.
Length: 7 feet 8 inches
Diameter: 1 foot 4 inches
Weight: 710 pounds
Dispenser: SUU-64/B Tactical Munitions Dispenser (TMD)
Warhead: The CBU-89 contains 72 BLU-91/B antitank (AT) and 22 BLU-92/B antipersonnel mines (AP). The BLU-91/B uses a target sensor to detect magnetic fields. When it detects an armored vehicle passing overhead, it fires a shaped charge into the belly of the vehicle. Upon impact, the BLU-92/B AP mine deploys trip wires. If disturbed, the AP mine explodes, sending high-velocity fragments over a wide area. The AP mines are mixed with the AT mines to discourage minefield clearance. Designed to deny the enemy use of terrain for a specific time period, both mines have time-programmable self-destruct mechanisms.
Guidance System: Ballistic
Control: The SUU-64/B has four tail fins that spin stabilize the dispenser after release from the delivery aircraft.
Propulsion: None
Unit Cost: $39,963
Date Deployed: mid-1980s

Delivery Aircraft: A-10, B-52H, B-1B, B-2, F-15E, F-16, and F/A-18.
Contractor: Aerojet-General Corporation, Honeywell, Alliant Techsystems, and Olin Corporation.



A CBU-89 Gator cluster bomb exhibited at the Hill Aerospace Museum. Photograph courtesy of the Hill Aerospace Museum.

Military Nomenclature: CBU-97

Name: Sensor Fuzed Weapon (SFW)

Description: The CBU-97 kills tanks. Designed to give tactical aircraft a means to disrupt an armor attack, the CBU-97 deploys forty hockey-puck shaped projectiles over a target area that averages 500 feet by 1,200 feet. Each projectile has an infrared sensor that can detect the heat emanating from the engines of tanks and support vehicles. When the projectile senses a heat source it fires an explosively formed penetrator into the target. The CBU-97 allows a single aircraft to kill many tanks on a single pass.

Employment Considerations: Cluster munition bomblets have a high dud rate - usually around five percent fail to explode on impact - and can scatter unexploded ordnance over a large area.

Because a single cluster bomb will cover a wide area, it will cause mas-

sive collateral damage if used in or near an area inhabited by civilian personnel.

The CBU-97 projectiles tend to cluster, and impact patterns do not uniformly cover the target area.

For successful employment, the delivery aircraft must release the CBU-97 no lower than 200 feet above the ground or higher than 20,000 feet.

When kinetic energy penetrators strike an armored vehicle, they punch a very small hole through the hull and kill the crew and destroy the vehicle through spalling (metal fragments shear off the inside wall as the penetrator breaks through the hull and bounce around inside the vehicle). This process leaves little evidence of vehicle destruction and often leads to multiple aerial attacks on a previously destroyed vehicle.

General Characteristics:

Range: Varies depending on release altitude.
Length: 7 feet 8 inches
Diameter: 1 foot 4 inches
Weight: 927 pounds
Dispenser: SUU-66/B
Warhead: The CBU-97 contains 10 BLU-108/B submunitions which house ten hockey-puck-shaped projectiles. After the CBU-97 releases from the aircraft, the SUU-66/B dispenser opens and ejects the BLU-108/B submunitions, which deploy parachutes to slow and stabilize their descent. At a preset altitude (sensed by the submunition's radar altimeter), the BLU-108/B fires a rocket motor that spins the submunition and powers it upward. During the ascent, the BLU-108/B slings the hockey-puck-shaped projectiles out over the target area. Once lofted over the target area, the projectiles' infrared sensors detect the heat from vehicle and tank engines. If they sense a heat source, the projectiles fire an explosively formed penetrator at the vehicle. The penetrator can defeat armor.
Guidance System: Ballistic
Control: Four tail fins give the CBU-97 flight stability.
Propulsion: None
Unit Cost: About $360,000
Date Deployed: 1997
Delivery Aircraft: A-10, B-52H, B-1B, B-2, F-15E, F-16, and F/A-18.

Contractor: Textron Defense Systems

A B-1B bomber drops a CBU-97 Sensor Fuzed Weapon. Photograph courtesy of the USAF.

Military Nomenclature: CBU-103

Name: Wind Corrected Munitions Dispenser

Description: The CBU-103 is a CBU-87 with a Wind Corrected Munitions Dispenser (WMCD) tail kit installed. The WMCD uses an inertial guidance system and movable control surfaces to achieve accurate delivery of cluster munitions from medium to high altitude. The CBU-103 delivers 202 BLU-97/B bomblets in a rectangular pattern. The size of the rectangle and the density of bomblets within it depend on the spin rate of the dispenser (the weapon offers six spin selections) and release parameters such as the height at which the dispenser bursts open and scatters the bomblets. Ordnance personnel can use a proximity fuze (a fuze that detonates at a specific height above the ground) or an electomechanical fuze (a fuze that explodes after a preset time delay) to open the dispenser. Cylindrical in shape, the BLU-97/B bomblet measures eight inches in length and two inches in diameter. Made of scored steel designed to break into 300 fragments capable of killing soldiers or puncturing armor, the bomblet case also has a zirconium ring to produce incendiary

effects. Planners use the CBU-103 against targets such as armored personnel carriers, artillery emplacements, and troops in the open.

Employment Considerations: Cluster munition bomblets have a high dud rate - usually around five percent fail to explode on impact - and can scatter unexploded ordnance over a large area.

Because a single cluster bomb will cover a wide area, it will cause massive collateral damage if used in or near an area inhabited by civilian personnel.

The U.S. military measures bomb accuracy using a calculation known as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The CBU-103 has a CEP of 30 feet.

The Wind Corrected Munitions Dispenser (WMCD) allows aircraft to accurately deliver cluster munitions from medium and high altitude reducing their exposure to enemy antiaircraft fire.

General Characteristics:

Range: Varies depending on release altitude.
Length: 8 feet 6 inches
Diameter: 1 foot 4 inches
Weight: About 1,050 pounds
Dispenser: SUU-65/B Tactical Munitions Dispenser with Wind-Corrected Munitions Dispenser (WCMD) tail kit installed.
Warhead: The CBU-103 contains 202 BLU-97/B bomblets. Cylindrical in shape, the BLU-97/B measures about eight inches in length and two inches in diameter. Made of scored steel designed to break into 300 fragments capable of killing soldiers or puncturing armor, the bomblet case also has a zirconium ring to produce incendiary effects.
Guidance System: The Wind Corrected Munitions Dispenser tail kit uses its inertial guidance system, signal processor, and movable tail fins to convert existing cluster munitions (CBU-87, -89, and -97) into inexpensive precision-guided munitions. The INS uses gyroscopes and accelerometers (instruments which detect motion) to determine changes in relative positions and guide the CBU-103 to the target. In route to the target, the WMCD can correct for bal-

listic errors and changing wind conditions.
Control: The WCMD has four movable tail fins that stabilize and provide directional control for the dispenser after release from the delivery aircraft.
Propulsion: None
Unit Cost: $30,153.35
Date Deployed: 1998
Delivery Aircraft: B-1B, B-2, B-52H, F-15E, F-16, and F-117.
Contractor: WCMD: Lockheed Martin
CBU-87: Aerojet-General Corporation, Honeywell, and Alliant Techsystems.

Ground crew mount a cluster bomb mated with a Wind Corrected Munitions Dispenser tail kit onto an aircraft pylon. Photograph courtesy of the USAF.

Military Nomenclature: CBU-104

Name: Wind Corrected Munitions Dispenser

Description: The CBU-104 is a CBU-89 with a Wind Corrected Munitions Dispenser (WMCD) tail kit installed. The WMCD uses an inertial guidance system and movable control surfaces to achieve accurate delivery of cluster munitions from medium to high altitude. Tactical aircraft drop the CBU-104 to create instant minefields. Like other members of the Gator mine system, the CBU-104 contains a mix of BLU-91/B antitank and BLU-92B antipersonnel mines. At what height the dispenser opens determines the size of the minefield. Ordnance personnel can use a proximity fuze (a fuze that detonates at a specific height above the ground) or an electomechanical fuze (a fuze that explodes after a preset time delay) to open the dispenser. The Gator mine system gives commanders a weapon that can deny the enemy key terrain, channel enemy forces into kill boxes, or trap an enemy force for later destruction.

Employment Considerations: Cluster munition bomblets have a high dud rate - usually around five percent fail to explode on impact - and can scatter unexploded ordnance over a large area.

Because a single cluster bomb will cover a wide area, it will cause massive collateral damage if used in or near an area inhabited by civilian personnel.

The U.S. military measures bomb accuracy using a calculation known as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The CBU-104 has a CEP of 30 feet.

The Wind Corrected Munitions Dispenser (WMCD) allows aircraft to accurately deliver cluster munitions from medium and high altitude, reducing their exposure to enemy antiaircraft fire.

When shaped charges strike an armored vehicle they punch a very small hole through the hull and kill the crew and destroy the vehicle through spalling (metal fragments shear off the inside wall as the shaped charge breaks through the hull and bounce around inside the vehicle). This process leaves little evidence of vehicle destruction and often leads to multiple aerial attacks on a previously destroyed vehicle.

General Characteristics:

Range: Varies depending on release altitude.
Length: 9 feet 1 inches
Diameter: 1 foot 4 inches
Weight: 810 pounds
Dispenser: SUU-64/B Tactical Munitions Dispenser (TMD) with Wind-Corrected Munitions Dispenser (WCMD) tail kit installed.
Warhead: The CBU-104 contains 72 BLU-91/B antitank (AT) and 22 BLU-92/B antipersonnel mines (AP). The BLU-91/B uses a target sensor to detect magnetic fields. When it detects an armored vehicle passing overhead, it fires a shaped charge into the belly of the vehicle. Upon impact, the BLU-92/B AP mine deploys trip wires. If disturbed, the AP mine explodes sending high-velocity fragments over a wide area. The AP mines are mixed with the AT mines to discourage minefield clearance. Designed to deny the enemy use of terrain for a specific time period, both mines have time-programmable self-destruct mechanisms.
Guidance System: The Wind Corrected Munitions Dispenser tail kit uses its inertial guidance system, signal processor, and movable tail fins to convert existing cluster munitions (CBU-87, -89, and -97) into inexpensive precision-guided munitions. The INS uses gyroscopes and accelerometers (instruments which detect motion) to determine changes in relative positions and guide the CBU-104 to the target. In route to the target, the WMCD can correct for ballistic errors and changing wind conditions.
Control: The WCMD has four movable tail fins that stabilize and provide directional control for the dispenser after release from the delivery aircraft.
Propulsion: None
Unit Cost: $60,383.25
Date Deployed: 1998
Delivery Aircraft: A-10, B-52H, B-1B, B-2, F-15E, F-16, and F/A-18.
Contractor:

WCMD: Lockheed Martin

CBU-89: Aerojet-General Corporation, Honeywell, Alliant Techsystems, and Olin Corporation.

An F-15E drops two Wind Corrected Munitions Dispensers. Photograph courtesy of the USAF.

Military Nomenclature: CBU-105

Name: Wind Corrected Munitions Dispenser

Description: The CBU-105 is a CBU-97 with a Wind Corrected Munitions Dispenser (WMCD) tail kit installed. The WMCD uses an inertial guidance system and movable control surfaces to achieve accurate delivery of cluster munitions from medium to high altitude. The CBU-105 kills tanks. Designed to give tactical aircraft a means to disrupt an armor attack, the CBU-105 deploys forty hockey-puck shaped projectiles over a target area that averages 500 feet by 1,200 feet. Each projectile has an infrared sensor that can detect the heat emanating from the engines of tanks and support vehicles. When the projectile senses a heat source it fires an explosively formed penetrator into the target. The CBU-105 allows a single aircraft to kill many tanks on a single pass.

Employment Considerations: Cluster munition bomblets have a high dud rate - usually around five percent fail to explode on impact - and can scatter unexploded ordnance over a large area.

Because a single cluster bomb will cover a wide area, it will cause massive collateral damage if used in or near an area inhabited by civilian personnel.

The U.S. military measures bomb accuracy using a calculation known as circular error probability (CEP). The CEP number is the radius of a circle around an aimpoint in which a weapon will land fifty percent of the time. The CBU-105 has a CEP of 30 feet.

The Wind Corrected Munitions Dispenser (WMCD) allows aircraft to accurately deliver cluster munitions from medium and high altitude, reducing their exposure to enemy anti-aircraft fire.

When kinetic energy penetrators strike an armored vehicle, they punch a very small hole through the hull and kill the crew and destroy the vehicle through spalling (metal fragments shear off the inside wall as the penetrator breaks through the hull and bounce around inside the vehicle). This process leaves little evidence of vehicle destruction and often leads to multiple aerial attacks on a previously destroyed vehicle.

General Characteristics:

Range: Varies depending on release altitude.
Length: 9 feet 3 inches
Diameter: 1 foot 4 inches
Weight: 1,027 pounds
Dispenser: SUU-66/B with Wind-Corrected Munitions Dispenser (WCMD) tail kit
installed.
Warhead: The CBU-105 contains ten BLU-108/B submunitions which house ten hockey-puck-shaped projectiles. After the CBU-105 releases from the aircraft, the SUU-66/B dispenser opens and ejects the BLU-108/B submunitions, which deploy parachutes to slow and stabilize their descent. At a preset altitude (sensed by the submunition's radar altimeter), the BLU-108/B fires a rocket motor that spins the submunition and powers it upward. During the ascent, the BLU-108/B slings the hockey-puck-shaped projectiles out over the target area. Once lofted over the target area, the projectiles' infrared sensors detect the heat from vehicle and tank engines. If they sense a heat source, the projectiles fire an explosively formed penetrator at the vehicle. The penetrator can

defeat armor.

Guidance System: The Wind Corrected Munitions Dispenser tail kit uses its inertial guidance system, signal processor, and movable tail fins to convert existing cluster munitions (CBU-87, -89, and -97) into inexpensive precision-guided munitions. The INS uses gyroscopes and accelerometers (instruments which detect motion) to determine changes in relative positions and guide the CBU-105 to the target. In route to the target, the WMCD can correct for ballistic errors and changing wind conditions.

Control: The WCMD has four movable tail fins that stabilize and provide directional control for the dispenser after release from the delivery aircraft.

Propulsion: None

Unit Cost: $371,216

Date Deployed: 1998

Delivery Aircraft: A-10, B-52H, B-1B, B-2, F-15E, F-16, and F/A-18.

Contractor: Textron Defense Systems

An F-16 dropping a Wind Corrected Munitions Dispenser. Photograph courtesy of the USAF.

CHAPTER 6: Aircraft Gun Systems

Military Nomenclature: M61A1

Name: Vulcan

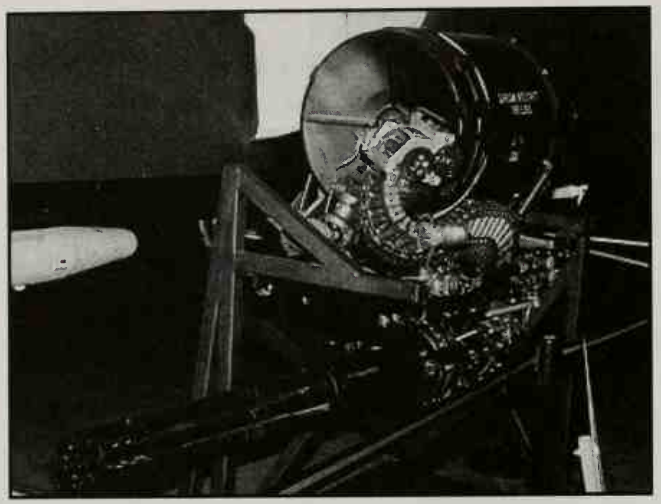
Description: An air-cooled, six-barrel, Gatling gun designed to provide saturation firepower. The cluster of six barrels rotates under power with each barrel firing once per revolution. This Gatling principle produces a high rate of fire but reduces heat and barrel erosion. The operator can select a rate of fire of either 4,000 or 6,000 rounds per minute. Aircraft that do not carry the M61A1 internally can mount the SUU-16/A external gun pod on weapons pylons mounted under the wings. The SUU-16/A consists of the M61A1 gun, an ammunition feed system, and an ammunition supply of 1,200 rounds. The M61A1 can engage and destroy aerial and ground targets.

Employment Considerations: With the gun firing 100 rounds a second, one-second bursts will give the pilot sufficient shot density to ensure a kill. A typical burst lasts two to three seconds.

General Characteristics:

Caliber: 20mm
Range: 1609 meters (1mile)
Length: 6 feet
Weight: 255 pounds (gun)
935 pounds (entire system)
Rate of Fire: 4,000 to 6,000 rounds per minute (the operator can select the rate of fire).
Muzzle Velocity: 3,400 feet per second
Ammunition: The M61A1 fires electrically primed armor piercing and high explosive incendiary 20mm ammunition.

Date Deployed: 1958
Carriage Aircraft: AC-130H/U, B-52H, F-14, F-15, and the F-16.
Contractor: General Dynamics



The M61A1 Vulcan cannon displayed at the USAF Museum.
Photograph courtesy of the U.S. Air Force Museum.

Military Nomenclature: M61A2

Name: Vulcan (Lightweight)

Description: An air-cooled, six-barrel, Gatling gun designed to provide saturation firepower. The cluster of six barrels rotates under power with each barrel firing once per revolution. This Gatling principle produces a high rate of fire but reduces heat and barrel erosion. The lightweight version of the M61A1, the M61A2 can engage and destroy aerial and ground targets.

Employment Considerations: With the gun firing 100 rounds per second, one-second bursts will give the pilot sufficient shot density to ensure a kill. A typical burst lasts two to three seconds.

General Characteristics:

Caliber: 20mm
Range: 1609 meters (1 mile)
Length: 6 feet
Weight: 200 pounds (gun)
860 pounds (entire system)
Rate of Fire: 4,000 to 6,000 rounds per minute (the operator can select the rate of fire).
Muzzle Velocity: 3,400 feet per second
Ammunition: The M61A2 fires electrically primed armor piercing and high explosive incendiary 20mm ammunition.
Date Deployed: 1987
Carriage Aircraft: AC-130H/U, F-15, F-16, F/A-18, and the F/A-22.
Contractor: General Dynamics

Sailors work on the Vulcan Gatling gun from an F/A-18 fighter. The M61A2 Vulcan has lighter components, such as barrels, than the M61A1. *Photo courtesy of the U.S. Navy.*

Military Nomenclature: GAU-12

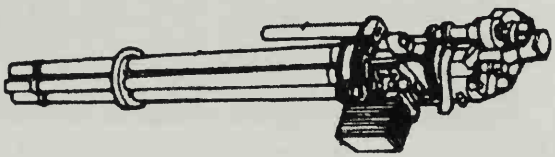
Name: Equalizer

Description: An air-cooled, five-barrel, Gatling gun designed to provide saturation firepower. The cluster of five barrels rotates under power with each barrel firing once per revolution. This Gatling principle produces a high rate of fire but reduces heat and barrel erosion. The operator can select a rate of fire of either 3,600 or 4,200 rounds per minute. The GAU-12 provides twice the lethality, longer stand-off range, and greater accuracy than earlier 20mm Gatling guns. A modified GAU-12 mounted on a trainable gun mount has increased the lethality of the AC-130U Gunship.

Employment Considerations: With the GAU-12's rapid rate of fire, one-second bursts will give the operator sufficient shot density to ensure a kill.

General Characteristics:

Caliber: 25mm
Range: 2,500 meters
Weight: 330 pounds
Length: 7 feet 2 inches
Rate of Fire: 3,600 rounds per minute (4,200 rounds per minute maximum fire)
Muzzle Velocity: 1,000 meters per second
Ammunition: The GAU-12 fires armor piercing and high explosive incendiary 25mm ammunition.
Date Deployed: 1983
Carriage Aircraft: AC-130U and the AV-8B.
Contractor: General Electric



The GAU-12 is a five-barrel Gatling gun.

Military Nomenclature: GPU-5

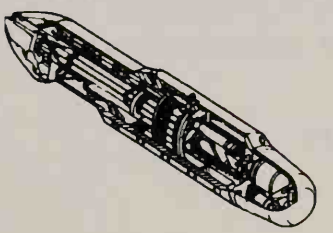
Name: 30mm Gun Pod

Description: A gun pod containing the GAU-13, an air-cooled, four-barrel, Gatling gun designed to provide saturation firepower. Lightweight and completely self-contained (it uses trapped air to power itself), the GPU-5 attaches to the weapons pylons of a wide variety of fighter and attack aircraft. The GAU-13 gives aircraft the ability to destroy tanks and armored vehicles.

Employment Considerations: With the GAU-13's rapid rate of fire, one-second bursts will give the operator sufficient shot density to ensure a kill.

General Characteristics:

Caliber: 30mm
Range: 1,250 meters
Weight: 1,368 pounds (empty)
1,909 pounds (loaded)
Length: 13 feet 10 inches
Diameter: 2 feet
Rate of Fire: 2,400 rounds per minute
Muzzle Velocity: 1,067 meters per second
Ammunition: The GAU-13 fires armor piercing and high explosive incendiary 30mm ammunition.
Date Deployed: 1979
Carriage Aircraft: F-15E
Contractor: General Electric and the Wayne Coloney Company



The GPU-5 gun pod contains the GAU-13 Gatling gun.

Military Nomenclature: GAU-8/A

Name: Avenger

Description: The GAU-8 is a 30mm, air-cooled, seven-barrel, Gatling gun designed to provide saturation firepower against ground targets. The gun fires a mix of armor piercing incendiary (API) and high explosive incendiary (HEI) rounds at 3,900 rounds a minute. Mounted only on the A-10 attack jet, the gun turns the A-10 into an efficient tank killer. While the gun has turned the A-10 into a "tank buster," it can also defeat an array of ground and aerial targets to include helicopters and slow moving aircraft.

Employment Considerations: The GAU-8 uses Depleted Uranium (DU) rounds to achieve its fame as a tank killer. A 30mm DU penetrator slug consists of DU alloyed with titanium encased in a thin aluminum shell. Environmental groups have attacked the use of DU rounds as nuclear pollution.

General Characteristics:

Caliber: 30mm
Range: 1,250 meters
Weight: 3,900 pounds (entire system)
661 pounds (gun)
Length: 20 feet (entire system)
9 feet 5 inches (gun)
Diameter: 1 foot
Rate of Fire: 3,900 rounds per minute
Muzzle Velocity: 1,067 meters per second
Ammunition: The GAU-8 fires armor piercing incendiary and high explosive incendiary ammunition.
Date Deployed: 1976
Carriage Aircraft: A-10
Contractor: General Electric

The GAU-8 Gun System gives the A-10 a big bite.
Photo courtesy of the Department of Defense.

Military Nomenclature: L60

Name: 40mm Bofors Light Anti-Aircraft Gun

Description: The L60 is a M2A1 anti-aircraft gun modified to operate as an air-to-surface weapon aboard the AC-130 Gunship. Modifications include a shortened barrel and the addition of a bell-shaped deflector. A single barrel, recoil-operated, air-cooled, 40mm gun, the L60 is loaded via a four round clip. The AC-130's crew must constantly feed the gun ammunition when it fires.

Employment Considerations: When friendly troops are near a close air support target, the forward air controller will use the term "danger close" in the call for fire. The munition employed will determine close proximity (600 meters is the standard for most munitions). The close proximity for the L60 is 125 meters.

General Characteristics:

Caliber: 40mm
Range: 3,000 meters
Weight: 1,000 pounds

Length: 12 feet
Rate of Fire: 120 rounds per minute
Muzzle Velocity: 2,870 feet per minute
Ammunition: The L60 fires armor piercing and high explosive incendiary 40mm ammunition.
Carriage Aircraft: AC-130H/U
Contractor: BOFORS

The barrel of a L60 protrudes from the side of an AC-130 gunship.
Photograph courtesy of the U.S. Air Force Museum.

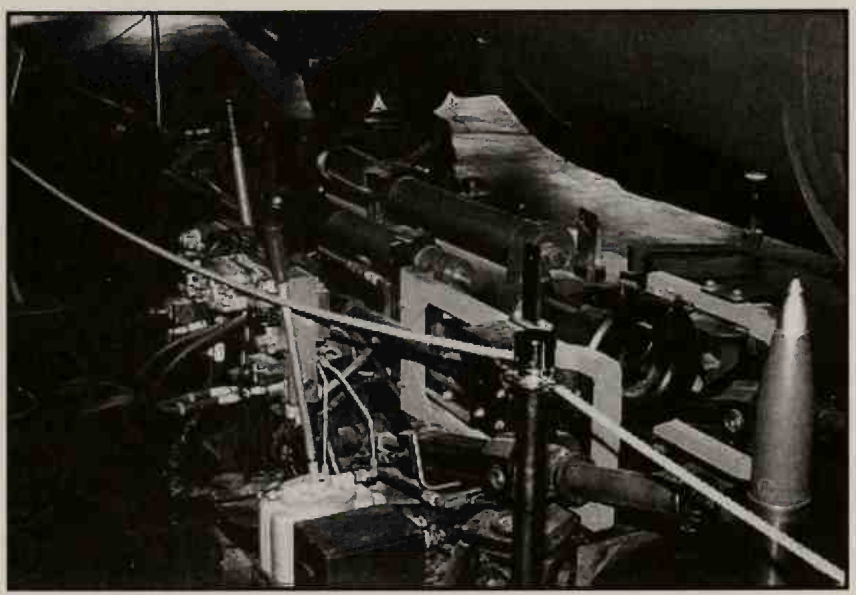
Military Nomenclature: M-102

Name: 105mm Howitzer

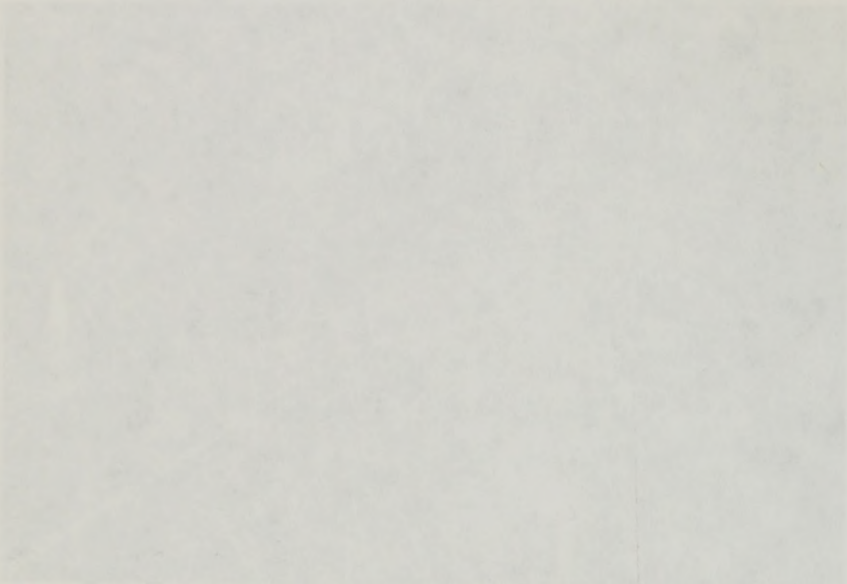
Description: A crew served 105mm howitzer mounted on a trainable gun mount and modified to fire from an AC-130 gunship.

Employment Considerations: When friendly troops are near a close air support target, the forward air controller will use the term "danger close" in the call for fire. The munition employed will determine close proximity (600 meters is the standard for most munitions). The close proximity for the M-102 is 200 meters.
General Characteristics:
Caliber: 105mm

Range: 11,200 meters
Weight: 1,450 pounds
Length: 10 feet 2 inches
Rate of Fire: 6 to 10 rounds per minute.
Muzzle Velocity: 494 meters per second
Ammunition available: The M-102 firest high explosive and white phosphorous ammunition.
Date Deployed: 1973
Carriage Aircraft: AC-130H/U (1 ea.)
Contractor: Inventory



The M-102 cannon and the 105mm shell it fires on display next to an AC-130 gunship. *Photograph courtesy of the U.S. Air Force Museum.*



CHAPTER 7: Aerial Torpedoes

Military Nomenclature: MK-46

Name: Lightweight Torpedo

Description: A torpedo is a self-propelled guided projectile that operates underwater and detonates on contact or in close proximity to its intended target. Designed to attack high-performance submarines, the MK-46 torpedo can launch from both fixed wing aircraft and helicopters as well as from submarines and surface vessels. Considered a lightweight torpedo, the MK-46 weighs about 518 pounds, it can operate in deep and shallow water. The MK-46 Mod 5 forms the backbone of the Navy's Anti-Submarine Warfare (ASW) torpedo inventory and the Navy expects it to remain in the inventory until 2015.

Employment Considerations: The MK-46 uses a bulk charge in its warhead. Bulk charges lack the penetration capability of a shaped charge, which is designed to explode in a direction.

Modern submarines produce very little noise and when they operate in shallow water, which generates a great deal of background noise, can prove difficult for the seeker to locate. The Mod 5A and Mod 5A(S) versions of the MK-46 incorporate improvements that enhance their performance in shallow water.

General Characteristics:

Speed: More than 28 knots (32.2mph)
Range: 8,000 yards
Depth: The MK-46 can dive to a depth in excess of 1,200 feet.
Length: 8 feet 6 inches
Diameter: 12.75 inches

Weight: About 518 pounds
Warhead: The warhead of the MK-46 contains 98 pounds of PBXN-103 high explosive. A bulk charge, it lacks the penetration capability of a shaped charge, which is designed to explode in a direction.
Guidance System: Once Launched, the torpedo will enter into either a snake-like search pattern or a circle (depending on inputs received prior to launch) to aid the seeker in its search for the target. The seeker can locate a target 1,600 yards distant. The guidance system can home on noise emitted by a submarine (passive homing) or it can use its sonar (active homing) to guide on the target. For that reason, the MK-46 normally uses its active mode to attack targets. The Mod 5 uses coded sonar pulses to overcome the signal noise created by bottom clutter in shallow water. When the torpedo's sonar begins active pinging, however, it alerts the target to its presence and gives it time to take evasive action. Anti-Submarine Warfare aircraft and helicopters overcome this obstacle by dropping torpedoes in the vicinity of the submarine, usually within 100 to 150 meters. At this short range, the submarine has little time to react before the torpedo strikes home.
Propulsion: A two speed, reciprocating external combustion engine propels the MK-46. It burns Otto II fuel (nitrogen ester mixed with an oxidant).
Unit Cost: About $840,000
Date Deployed: 1966 (MK-46)
1979 (MK-46 Mod 5)
Delivery Aircraft: P-3C, S-3B, and the SH-60B/F.
Contractor: Alliant Techsystems

Considered a lightweight torpedo, the MK-46 can launch from fixed wing and helicopter aircraft. *Photo courtesy of the U.S. Navy.*

Military Nomenclature: MK-50

Name: Advanced Lightweight Torpedo

Description: A torpedo is a self-propelled guided projectile that operates underwater and detonates on contact or in close proximity to its intended target. Designed for use against fast, deep-diving nuclear submarines, the MK-50 torpedo can launch from both fixed wing aircraft and helicopters as well as from submarines and surface vessels. Intended to gradually replace the MK-46 torpedo, it has proved expensive (twice the price of the MK-46), which has limited the number purchased.

Employment Considerations: To remain lightweight, aerial torpedoes carry a smaller warhead. Many modern submarines have double hulls made of titanium that can defeat small, conventional warheads. To destroy these vessels, the MK-50 uses a shaped charge, an explosive designed to explode in a direction. The MK-46 uses a less effective bulk charge warhead.

Modern submarines can operate at speeds that allow them to take evasive action against torpedoes. The MK-50 can close on the target at more than 46 mph compared to the MK-46's more than 32 mph speed.

General Characteristics:

Speed: More than 40 knots (about 46 mph)
Range: Classified
Depth: The MK-50 can dive to a depth in excess of 1,900 feet.
Length: 9 feet 4 inches
Diameter: 12.75 inches
Weight: 750 pounds
Warhead: The warhead of the MK-50 contains 100 pounds of high explosive. A shaped charge – an explosive charge designed to explode in a direction-the warhead can penetrate the titanium double hulls of modern submarines.
Guidance System: The guidance system can home on noise emitted by a submarine (passive homing) or it can use its sonar (active homing) to guide on the target. Modern submarines produce little noise and when they operate in shallow water, which generates a great deal of background noise, can prove

difficult for the seeker to locate. For that reason, the MK-50 normally uses its active mode to attack targets. When the torpedo's sonar begins active pinging, however, it alerts the target to its presence and gives it time to take evasive action. Anti-Submarine Warfare aircraft and helicopters overcome this obstacle by dropping torpedoes in the vicinity of the submarine, usually within 100 to 150 meters. At this short range, the submarine has little time to react before the torpedo strikes home.

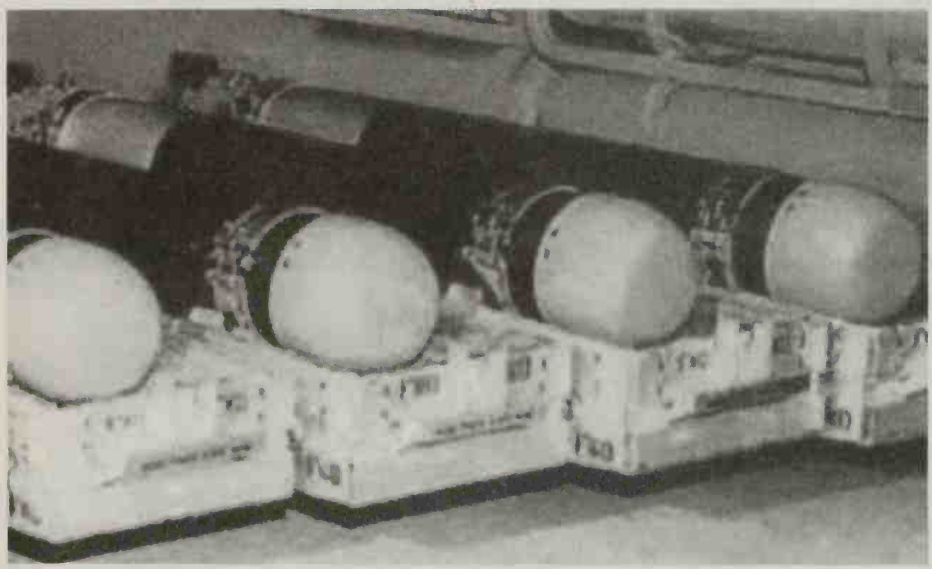
Propulsion: The MK-50 uses a stored chemical energy propulsion system.

Unit Cost: $2.9 million

Date Deployed: Low rate production for operational testing began in the late 1980s. Significant performance deficiencies remain despite some modifications to the torpedo. While tactical employment from aircraft has received approval, the torpedo remains in low rate production and its numbers limited.

Delivery Aircraft: P-3C, S-3B, and the SH-60B/F.

Contractor: Alliant Techsystems, Northrup Grumman, and Raytheon Electronic Systems.



The MK-50 can defeat fast, deep-diving submarines. *Photograph courtesy of the U.S. Navy.*

Glossary

Accumulator: A key component of a hydraulic system, the accumulator stores energy to enhance system performance. The harsh environment of a missile launch and flight can disrupt the flow of fluid in a hydraulic system; the stored energy in the accumulator ensures that power is available when needed.

Active radar: A guidance radar that emits and homes on radar signals it emits.

AGM: An Air Force acronym for air-to-ground missile. A missile launched from an aircraft at a ground-based target. The Navy defines AGM as an air-launched, surface attack guided missile.

AIM: An acronym for Air Intercept Missile. A missile designed to down aerial targets.

Annular blast fragmentation warhead: A warhead designed to explode in a ring-shaped pattern.

BLU: An acronym for Bomb Live Unit. A bomb body filled with explosive.

Boresight: The direction in which the nose of a missile points.

Canards: Small wings usually attached near the front of the missile or bomb.

CBU: An acronym for Cluster Bomb Unit. A bomb consisting of a cigar-shaped dispenser that dispenses hundreds of submunitions over a large area.

Chord: The distance between the leading edge and the trailing edge of a wing is called the wing chord.

Continuous-rod warhead: A warhead in the shape of a rod made of a large number of small rods connected at each end and formed around a quantity of high explosive. When the high explosive explodes it throws the rods

into a tight ring of steel. This ring holds its tight pattern longer than a cloud of traditional shell fragments, making it more lethal to aircraft. It also weighs less than a traditional fragmentation warhead.

Delta wings: Symmetrical triangular wings designed to fly at subsonic or supersonic speeds.

Desired Mean Point of Impact (DMPI): Preprogrammed geographical coordinates fed into the guidance computer of GPS guided munitions to strike a specific location. Planners derive these "geocoordinates" by fusing reconnaissance imagery with three-dimensional data, a process called "mensuration".

Destex: The Navy prefers to use desensitized (less likely to explode from heat or shock) explosives in its aerial munitions because of the possibility of fuel fires aboard its aircraft carriers. Destex is a desensitized Tritonal high explosive.

Doppler radar: A radar that can determine the phase shift in returning radar signals. You have experienced this phase shift – known as the Doppler Effect – when listening to a train whistle. As the train approaches the pitch of the whistle gets higher; when the train passes the pitch of the whistle lowers. By determining the frequency of outgoing and incoming radar signals, the Doppler radar can determine the location and velocity of moving objects.

Electro-mechanical actuator: A device that turns control signals into movement by providing either a pushing or pulling force, usually by advancing or withdrawing a ram (a long rod).

Fire and forget weapon: A weapon that once launched from the delivery aircraft needs no further input or action from the aircraft's systems or flight crew to strike its target.

GBU: An acronym for Guided Bomb Unit. A general-purpose or penetrator bomb with a guidance kit installed.

Global Positioning System (GPS): A constellation of 27 (24 operational and 3 spares) Earth-orbiting satellites used by GPS receivers to deduce their own location. A GPS receiver can determine its location if it can receive the

signal from four or more GPS satellites. The navigation systems of most guided munitions incorporate a GPS receiver. By knowing where it is at all times, a guided munition can accurately strike another position.

Imaging infrared system: An imager that detects heat emitted by objects to form crude pictures displayed on a monitor inside the launch aircraft. Imaging infrared systems allow the use of optically guided precision munitions at night and in adverse weather.

Inertial Navigation System (INS): An inertial guidance system uses gyroscopes and accelerometers (instruments which detect motion) to determine changes in relative positions and guide the weapon to the target.

Joint Direct Attack Munition (JDAM): A general-purpose bomb or penetrating warhead mated with a JDAM kit. The JDAM kit consists of a Global Positioning System (GPS) receiver, a guidance computer that couples both GPS and Inertial Navigation System (INS) navigation, and adjustable airfoil fins that give the bomb guidance capability.

Joint Helmet Mounted Cueing System (JHMCS): A pilot helmet with targeting capability. The JHMCS projects a "heads up" display inside the visor that shows sensor and weapons data as well as flight data such as airspeed and altitude. The pilot can aim sensors and weapons by turning his head to the appropriate display icon and pressing a switch on the flight controls. The advantage of the JHMCS is that the pilot can fly the aircraft and target and launch weapons without looking inside the cockpit.

JP-10: A high-density synthetic fuel used to power turbine missile engines.

LGB: An acronym for Laser Guided Bomb. A general-purpose or penetrator bomb with a laser guidance kit installed.

MilliMeter-Wave (MMW) radar: The MMW provides precise range and speed measurements regardless of environmental conditions and a wide scan arc. These characteristics give an attack helicopter using a MMW the ability to rapidly search an area for targets and engage in adverse weather conditions.

Passive radar: The guidance radar of a weapon that homes on radar signals emitted by the launch aircraft.

Paveway Laser-Guided Bomb: A family of laser-guided bombs first used in 1968. A Paveway laser guidance kit includes a nose-mounted laser guidance unit, which includes small wings called canards. The guidance unit steers the bomb to a target illuminated by an external laser source. To steer the bomb, the guidance unit moves its canards. The Paveway kit also contains tail-mounted flight stability fins that provide additional lift and extend the range of the bomb. The Paveway family of LGBs consists of three generations – Paveway I (now obsolete), Paveway II, and Paveway III.

PBX explosives: an acronym for Plastic Bonded Explosives, a family of explosives that contain high explosives such as HMX, HNS, PETN, or RDX mixed with a polymeric binder. Weapon designers can make safe and reliable weapons using a PBX explosive. PBXs provide high mechanical strength, insensitivity to handling and shock, and relative insensitivity to heat.

Penetrator warhead: A penetrator warhead has a slim shape and a thick nose and side walls that allow it to survive impact and penetration of hardened surfaces and structures.

Proximity fuze: A fuze that explodes a warhead when it has closed within lethal range of the target.

Semi-active radar: The guidance radar of a weapon that homes on radar signals emitted by the launch aircraft.

Semi-Armor-Piercing (SAP) warhead: A warhead designed to penetrate armor before it explodes to ensure maximum damage to the target.

Shaped charge: A shaped charge focuses its explosive power into a small stream that cuts through armor and other hardened structures.

Strakes: Small wings placed upstream of a main wing to change the downstream vertical flow. Strakes can increase lift and control.

Terminal pop-up maneuver: Missiles that hug the terrain or skim the sea en route to the target (this allows them to escape enemy radar and defense systems) will normally perform a rapid climb (a pop-up) as they near the target. The pop-up allows the missile to acquire and attack the target.

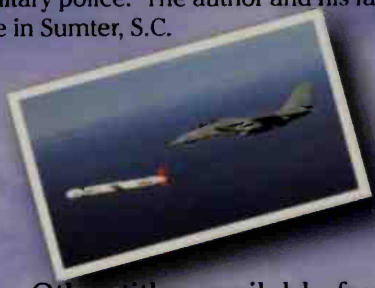
Terrain Contour Matching (TERCOM): A navigation system that compares the elevation of the terrain it flies over with the electronic maps it has stored in its software. This comparison allows TERCOM to determine its position.

Weapon Systems Officer (WSO): A member of an aircrew responsible for operation of the aircraft's weapon systems.

The End

About the Author

David F. Crosby writes history for the 9th Air Force History Office. The 9th Air Force commands US Air Force and Coalition Air Force units serving in the Central Command Area of Responsibility. Previously, the author worked as the aerospace and defense writer for Hoover's Inc., and has written numerous articles for publications such as *Civil War Times Illustrated*, *Wild West*, and *True West*. He also served in the U.S. Army in the airborne infantry and the military police. The author and his family live in Sumter, S.C.



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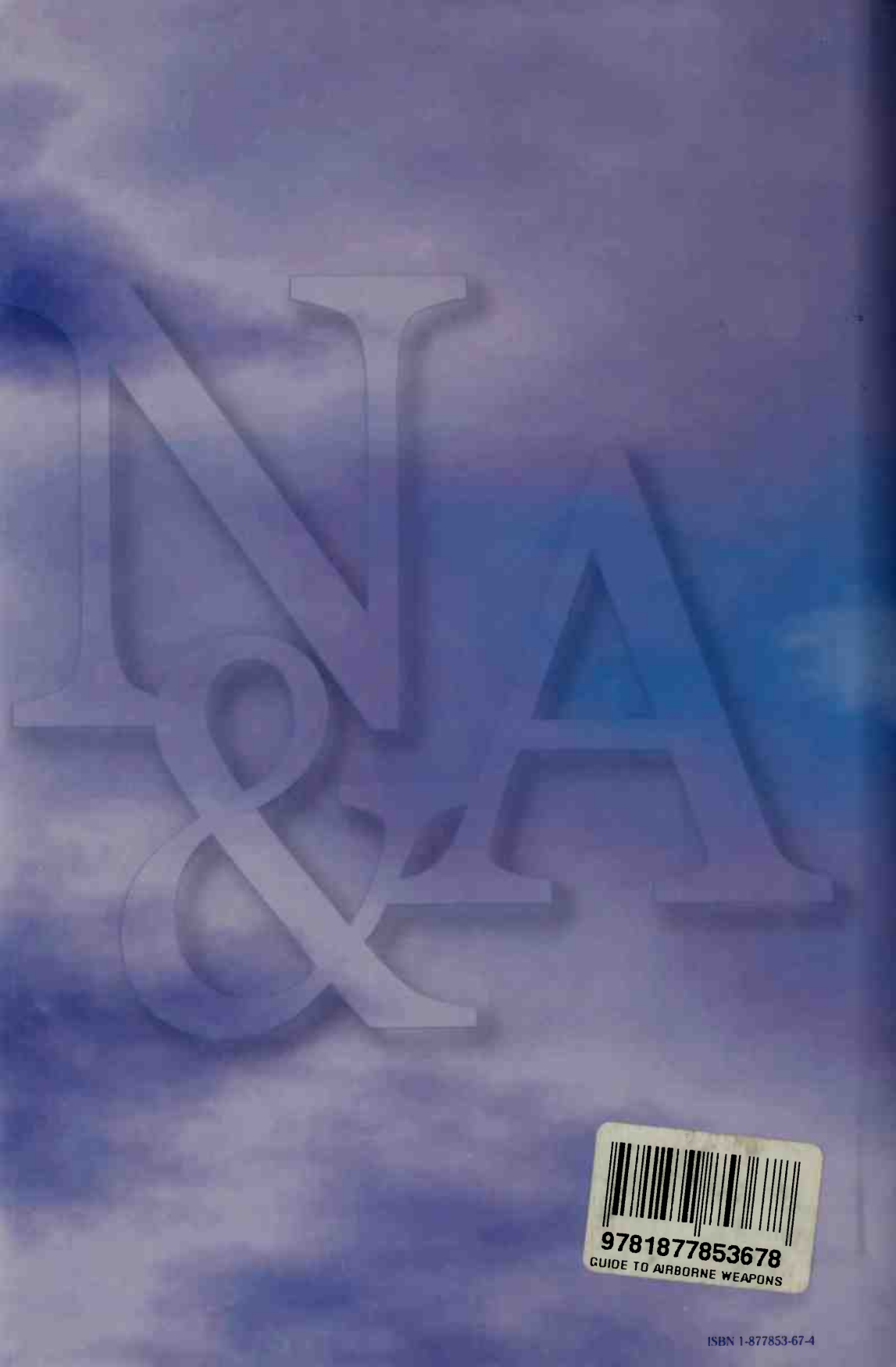

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